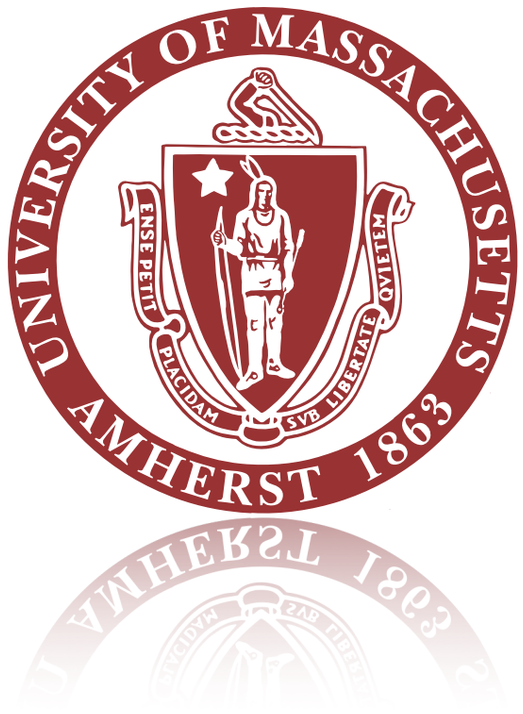
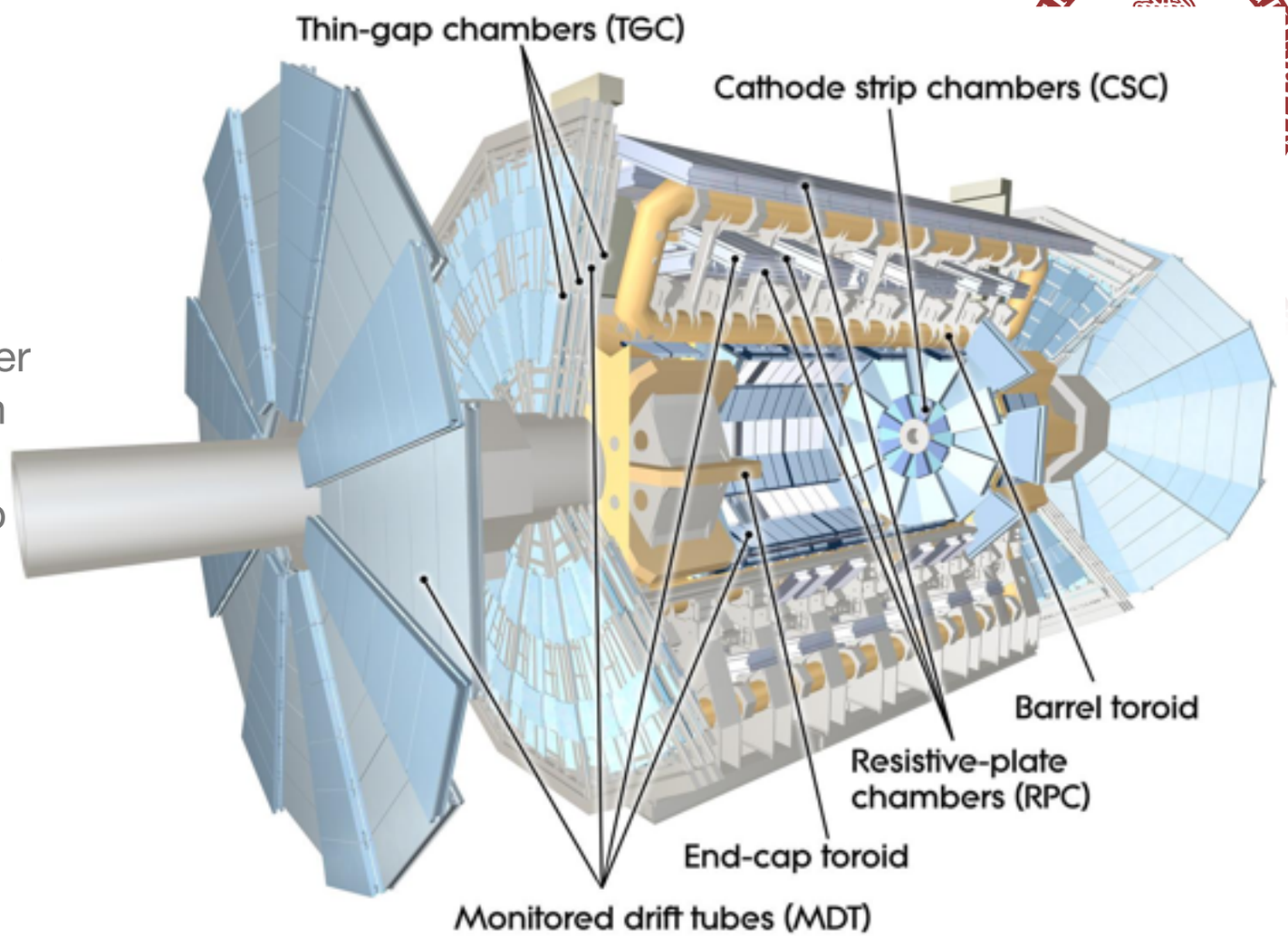


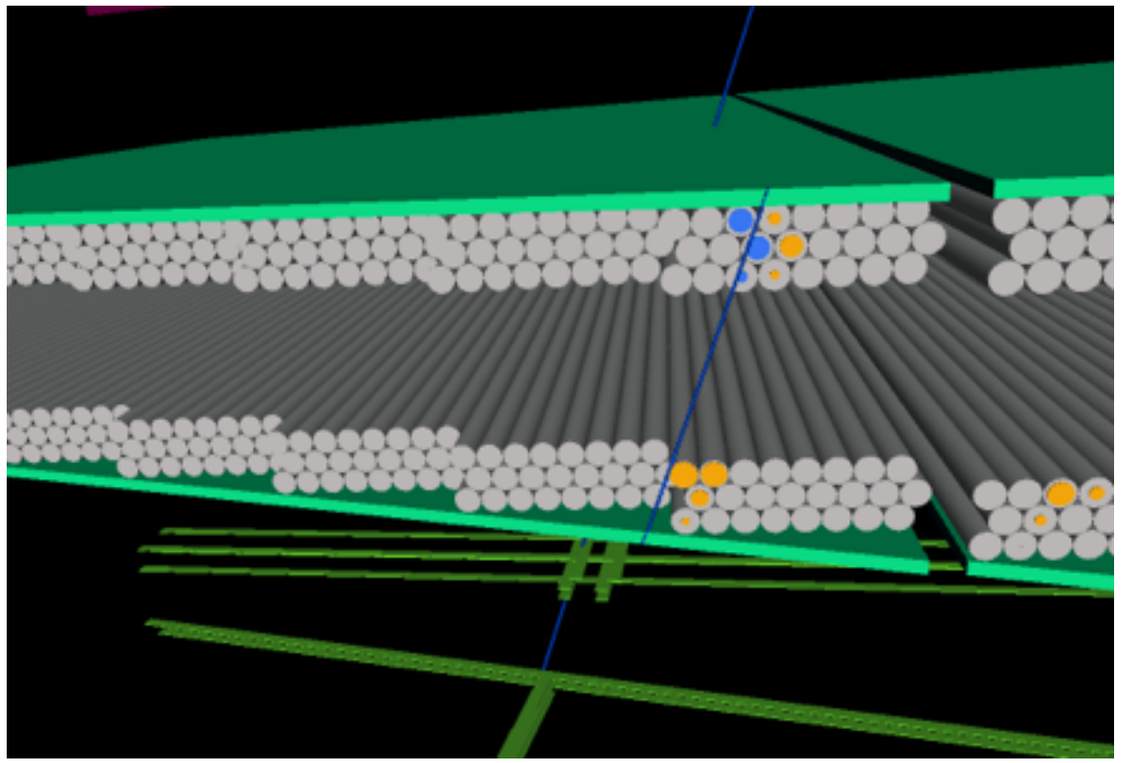
Muon reconstruction

Edward Moyse

Muon Spectrometer

- The Muon Spectrometer forms the outer layer of ATLAS and is designed to detect tracks in the region 0 < |eta| < 2.7. It consists of a barrel section and two endcaps, all made up of three layers of chambers fitted around toroidal magnets. Four types of chamber technologies are used:
  - Monitored Drift Tubes(MDT)-precision measurements (80um per tube) in the bending plane
- Cathode Strips Chambers (CSC) - used in the forward regions (2<|eta|<2.7) with a resolution of ~60um in the bending (eta) plane , and 5mm in the transverse plane (phi).
- Resistive Plate Chambers (RPC) and Thin Gap Chambers (TGC)-used by the trigger and provide eta and phi measurements with a resolution of ~1cm each





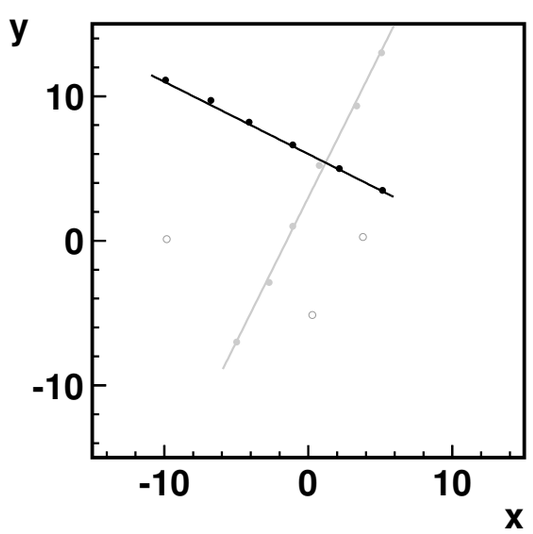
Muon reconstruction

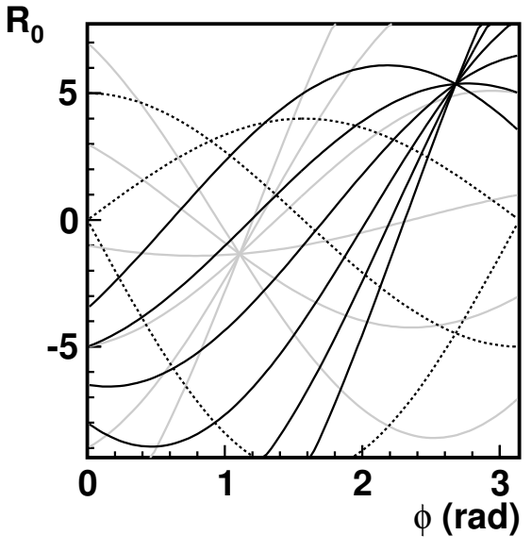
- Very different challenges to Inner Detector
  - High background level present in the ATLAS experimental hall which yields high single tube occupancy may spoil or mask muon hits and create fake track segments from combinatorial hit associations
  - Large variety of the muon chambers and the complexity of the layout
  - The large distances between measuring stations causes significant extrapolation uncertainties.
  - The high inhomogeneity of the magnetic field and dead material prevents the use ofsimple analytical shapes for muon tracks of these chambers
- Reconstruction proceeds in several steps:
  - Pattern finding
  - Segment building
  - Track finding

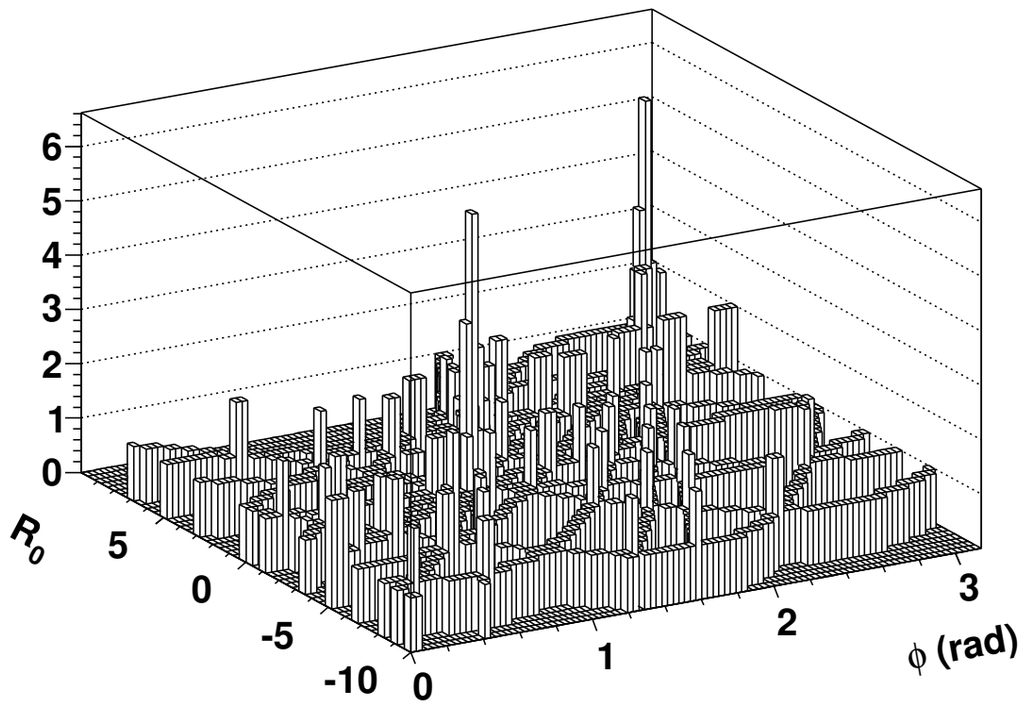
https://indico.cern.ch/event/394320/contribution/2/attachments/789437/1082040/MuonRecoOverview.pdf

Hits pattern finding

- Use 2D Hough transform using (R0,φ)
- The Hough transform
  - transforms points in the x,y space into lines in R0,φ
  - straight lines in the xy plane are points in the Hough space
    - the lines of all hits from a given line cross in one point in the Hough space
      - when combined with a histogramming technique the problem reduces to finding the bins with the highest value in the histogram
- Advantages of the method
  - very good background rejection properties
  - complexity almost linear with number of hits

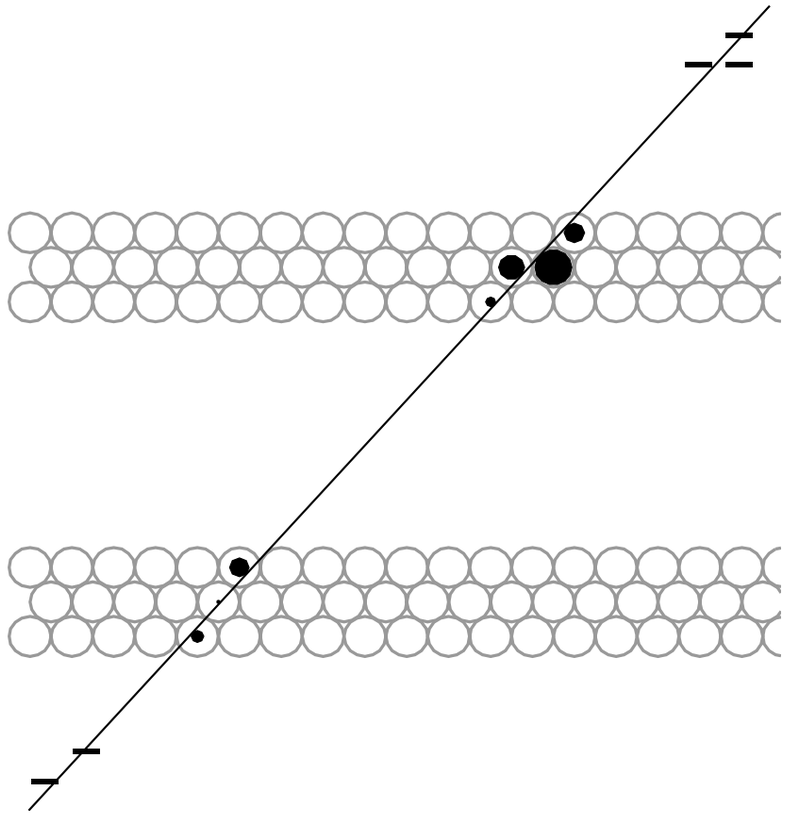






Segment finding (MDT)

- **Local segment finding in the individual MDT stations offers a powerful way of reducing combinatorics**
  - the bending of muons above p = 3 GeV is sufficiently small: their trajectory can be approximated by a straight line
  - MDTs provide a very high precision measurement of the trajectory of the muon (80μm average resolution) -> good background rejection
  - trigger confirmation can be used to reduce out-of-time background

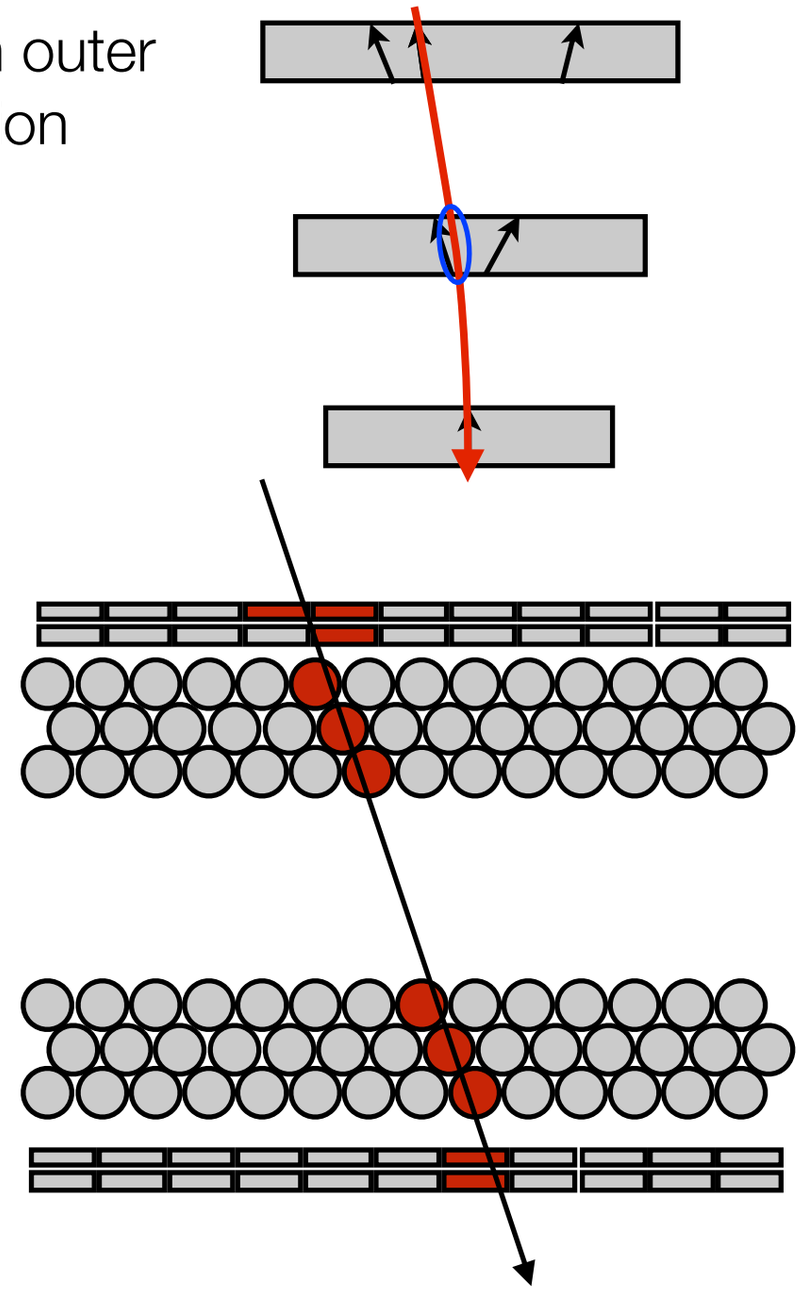


https://indico.cern.ch/event/394320/contribution/2/attachments/789437/1082040/MuonRecoOverview.pdf

Track finding

- **Four stage track reconstruction**
  - Select high quality seed segment
  - Look for chambers crossed by the track without hits
  - Calculate track intersection with the chamber
    - Search for hits in a road around the intersection
  - Add hits to the track
    - First add trigger hits (if any) and refit
    - Run MDT segment finding if more than three MDT hits are within the road
  - Rerun hole search if any hits were added
  - Add crossed channels without hits to the track as holes

Seed in outer station



Muon reconstruction

- Final stage is combination (not covering in any detail here):
  - Combined muons - ID + MS hits, full refit
    - Can also be ID seeded - i.e. extrapolate ID track to MS and start reconstruction in that road
  - Standalone muons - no ID track, so just MS
  - Segment tagged muons - ID track + matching segment
  - Calo tgged muons - ID track + matching calorimeter energy deposit
- Code is already highly optimised
  - Competition between competing software chains, and various software reviews
  - Code used in trigger, where performance is very important
  - Recently largely re-written
  - LOTS of details in summary talk from Niels here:
    - https://indico.cern.ch/event/279845/session/0/contribution/1/attachments/512634/707448/TrackingLectureMuons.pdf

Future muon reconstruction

- Truthfully, not much thought put into this yet
  - Code already very fast relative to the rest of ATLAS - with limited resources, not high priority
  - Pattern recognition starts in independent chambers - so should be very amenable to parallelism.
    - But this stage of the reconstruction is very fast (not visible to the right)
- Time is mostly taken with combinatorics between chambers… certainly can be improved, but not nearly so easy…