DATA CHALLENGE INTRODUCTION

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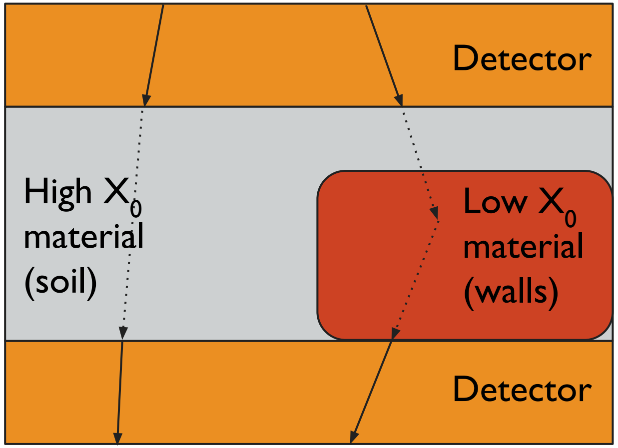
INTRODUCTION TO THE TASK

- Britain's oldest city, Colchester, was founded by the Romans around 40AD as a barracks on the site of a Celtic stronghold
- Throughout the 2nd & 3rd centuries, the city expanded, eventually becoming a *colonia* -- an extension of the city of Rome
- Roman landmarks remain to this day, with more discoveries still being made
- Whilst performing some construction, workers uncovered indications of ruined walls in a site that was previously thought to be empty
- You have been brought in to scan the site using *muon tomography* and to map out the locations of the walls to help aid the archeologists

Example of Roman walls in Colchester, credits Maria,

TOMOGRAPHY VIA MULTIPLE SCATTERING

- Muon tomography allows us to infer the material composition of unknown volumes of space
- Cosmic muons are scattered by materials in the volume according to their radiation-length (X_0 [m]) of the material
    - Radiation-length = average distance between scatterings
- By using detectors, we can measure muons above and below volume
    - The changes in trajectory provide information on material composition



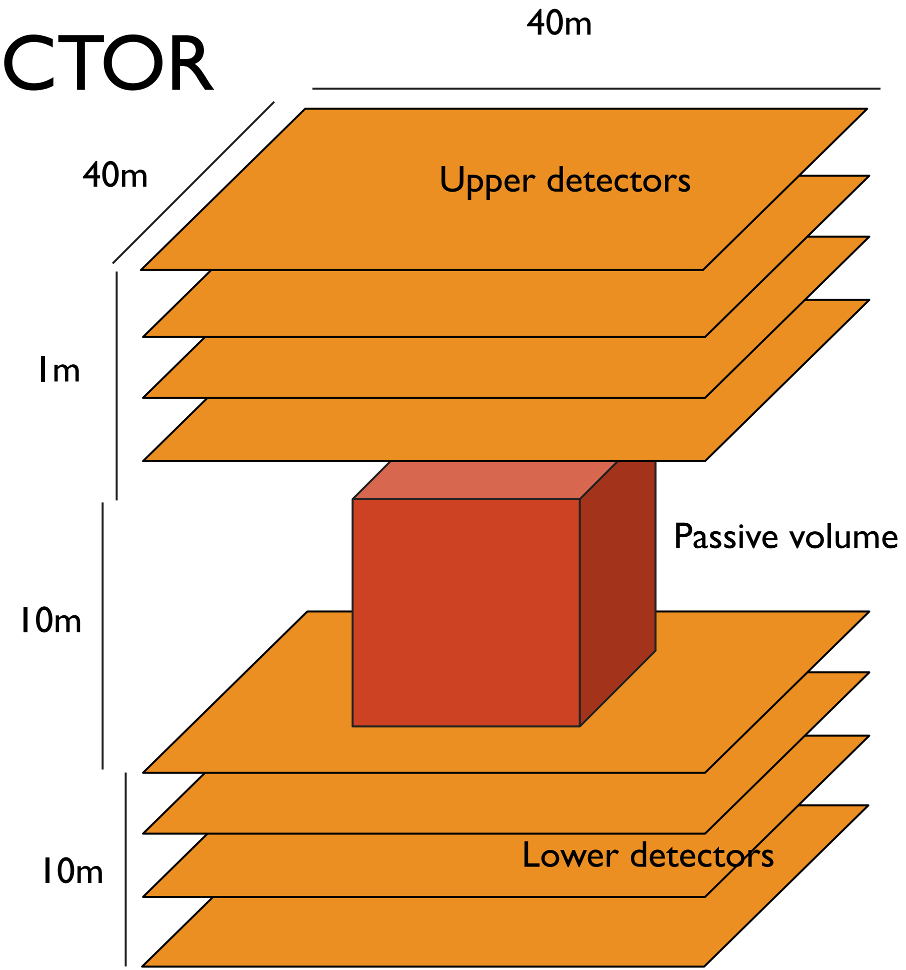
High X_0 = low scattering

Low X_0 = high scattering

X_0 = average distance between scatterings

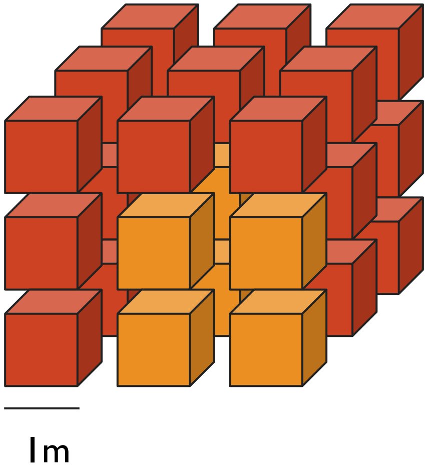
DETECTOR

- The detector setup used here is quite unrealistic
  - It assumes that a detector panel may be placed underground, directly under the passive volume
  - The simulated detector is very large (40x40m), but this is for simulation convenience; a smaller detector could be used and placed in several spots to create a combined scan
- The detector consists of two layers (1m height), placed above and below the volume
  - Each layer contains 4 equally spaced panels
  - Each panel records muon positions with an xy resolution of 0.1mm



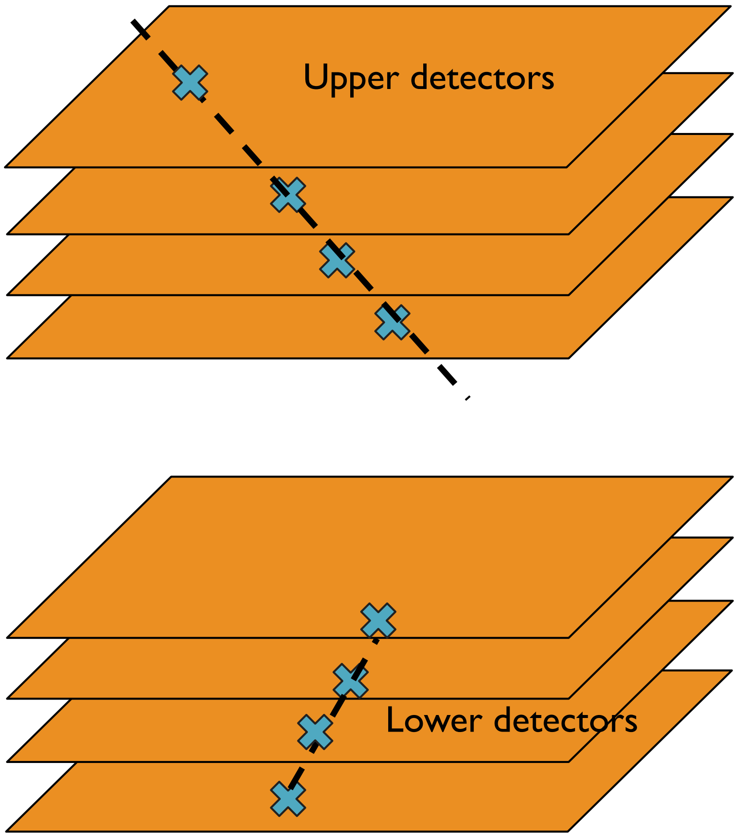
PASSIVE VOLUME

- The passive volume is a 10x10x10m cube
  - It is subdivided into 1000 voxels, each 1x1x1m in size
- Each voxel can either be soil (X0=~0.26m) or wall (X0=~0.08m)
  - The amount of muon scattering depends on the voxel X0, and scales as sqrt(distance/X0)/momentum
  - Muon momentum will always be 1GeV, but the distance depends on the incoming angle



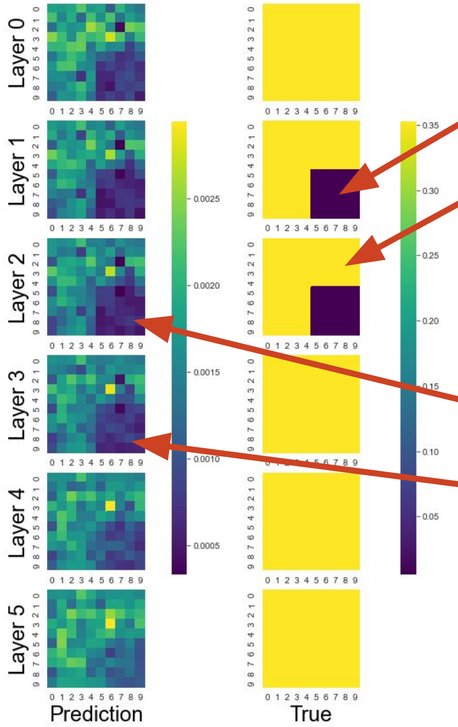
TRACK FITTING

- Fit linear trajectories to the hits
- Can then compute variables about the muon scattering, e.g.:
  - Incoming and outgoing angles
  - Changes in trajectory



POCA INFERENCE

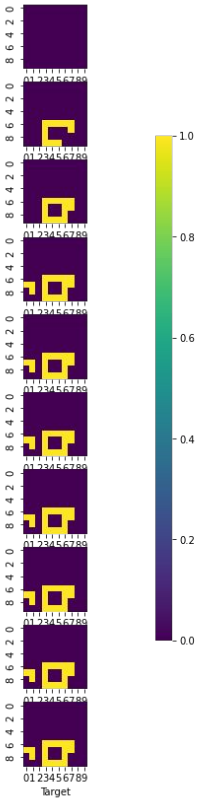
- PoCA method assigns the entirety of the muon scattering to a single voxel
- The voxel is chosen by extrapolating trajectories inside the passive volume to find the Point of Closest Approach
- X0 predicted by inverting the scattering model to get X0 as a function of total scattering, and then averaging over many muons
- Slight modification: X0 predictions are applied to every voxel, but in an average weighted by the probability of the scattering having occurred there
  - Computed using the uncertainty on the PoCA location
  - This provides a dense set of voxelwise X0 predictions



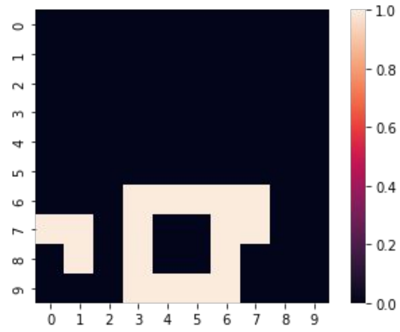
- Block of lead (X_0=0.005612m) Surrounded by beryllium (X_0=0.3528m)
- Predictions highly biased to underestimate X_0
- Lead block clearly visible
- but high z uncertainty in scatter location causes ‘ghosting’ above and below

TARGET

- The passive volumes are randomly generated to simulate stone walls buried underground
  - Each volume contains at least one wall, surrounded by soil
- All walls begin on the same "old ground-level" level, but can vary in height
  - The "old ground-level" can vary between samples



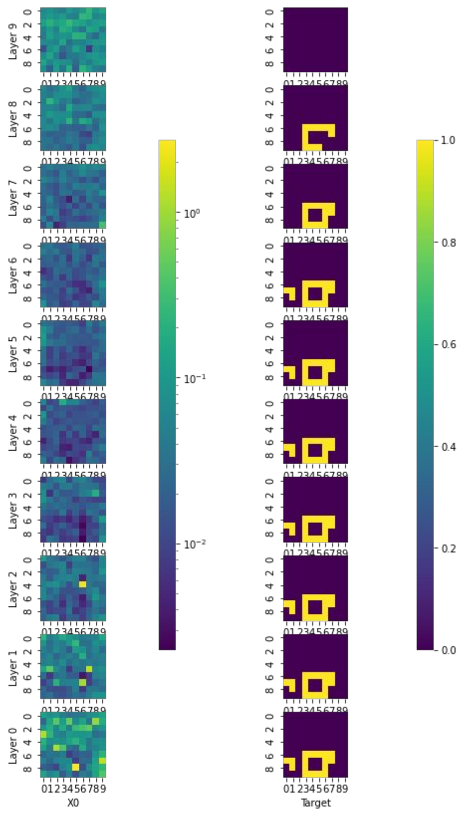
XY slices in layers of z



Top-down image

DATASET

- A sample is created by scanning a newly generated passive volume:
  - 10,000 muons (momentum = 1GeV)
  - Incoming angle and initial xy position can vary
  - This results in a biased PoCA image of voxelwise X0 predictions (float32)
  - The target is a map of the wall voxels (int, 0 = soil, 1 = wall)
- Approximately 100k labelled samples are provided along with 30k unlabelled testing samples
  - Your task is to provide predictions on the unlabelled sample



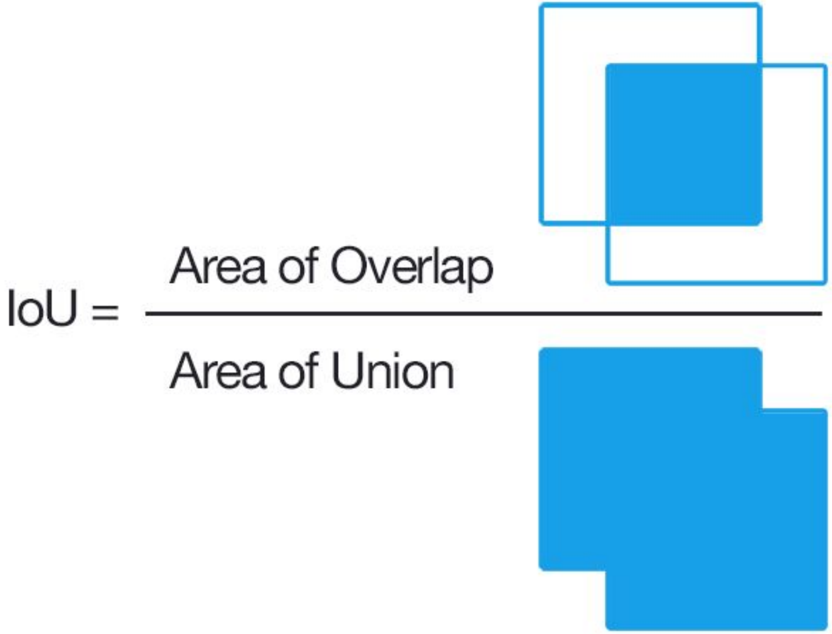
Example sample:

Left = voxelwise X0 predictions

Right = map of voxels which contain wall

METRIC

- Both predictions and targets will be a voxelwise 0 or 1
- Performance evaluated using the "intersection-over-union" (IOU) metric
- IOU computed separately for soil and wall and then averaged.
- E.g. for wall (target=1):
  - Intersection is number of correctly predicted voxels
  - Union is the sum of the number of voxels predicted to be 1 and the number of voxels which are actually 1
- IOU is between 0 and 1, and higher values mean better performance

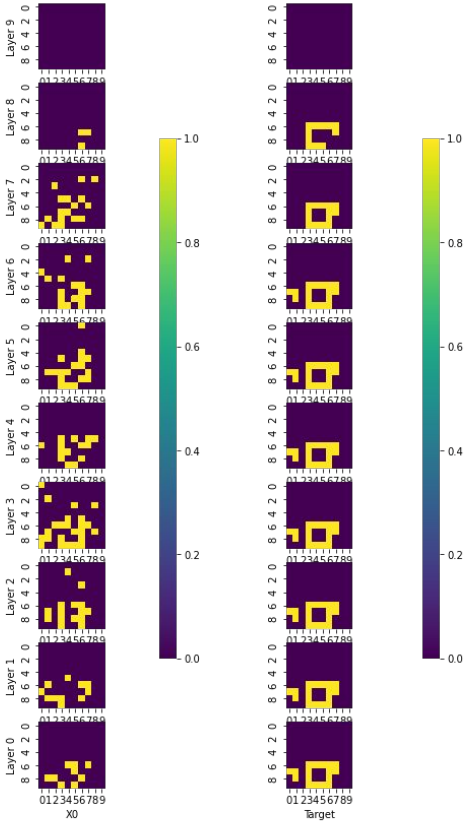


STARTER PACK

- Starter notebook covers:
  - Loading the data and viewing the data
  - Applying a simple threshold-based approach
  - Evaluating performance using the intersection-over-union metric
  - Creating a submission with predictions for the test data
- Threshold method: prediction based solely on X0 values:
  - X0 below threshold, predict wall
  - X0 above threshold, predict soil
  - Optimise thresholds by maximising the IOU

Left: predictions using the optimised threshold

Resulting IOU is 0.63



SUBMISSIONS

- Submissions must be uploaded in HDF5 format to https://cernbox.cern.ch/index.php/s/ylsOYg9q7hcRk4l
  - Format must be a (sample, z, x, y) matrix of integer values stored in a dataset called 'preds'
    - Submissions not in this format will be ignored
  - Order of predictions must be the same as the samples in the testing dataset
  - The starter pack contains instructions on how to do this
  - File names should include your name and an optional ID number for the submission
    - In case of multiple submissions, I will use the one with the highest ID number
    - Files without a person's name will be ignored
- Deadline is 23:59:59 CEST on 22/09/04

- Submissions can be made anytime before the deadline
- Multiple submissions are ok
  - Final results will be based on the latest submission
- Every Friday I will announce results of performance on a random subsample of the test data using everyone's latest submissions.
  - I will also let anyone know if their submission format was invalid
- The final results will be computed using the remaining samples from the test dataset