# Measurements of the material budget with EUTelX0Processor

## A new tool implemented as part of the EUTelescope Project

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Measurements of the material budget with EUTelX0Processor
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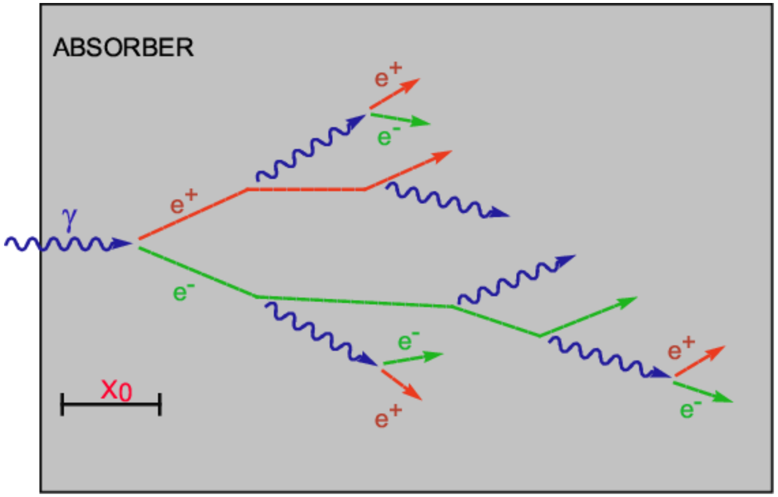
HELMHOLTZ | ASSOCIATION

DESY

# Contents

# The material budget

- Electrons passing through material lose energy.
- Results of this include electron showers and scattering.
- Scattering is dependant on the thickness of the material in terms of $X_0$
- The material budget, or radiation length, has two equivalent definitions:
- The average distance over which an electron is reduced to 1/e of its original energy (bremsstrahlung)
- 7/9th of the photons mean free path (pair production)




[2] – Image from "Cosmic rays tracks on the PICsIT detector", *Segreto et. al.*

# Multiple scattering

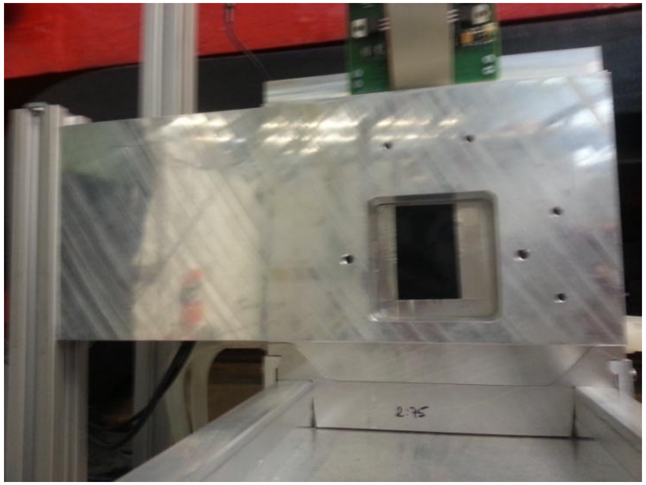
- The radiation length can be worked out empirically, there is no known analytical solution in a thick material.
- The amount of multiple scattering in a material is dependant on the radiation length, but it is also a stochastic process.
- The mean multiple scattering angle is zero, but the variation increases with $X_0$. The Particle Data Group gives the Highland formula as its best guess at a model (there are other methods too):
- Highland formula: $\theta_0 = \frac{13.6\,\mathrm{MeV}}{\beta cp} z \sqrt{\frac{x}{X_0}} \left[1 + 0.038 \ln\left(\frac{x}{X_0}\right)\right]$

$\theta_0$ = RMS of scattering angle
z = chargeof incoming particle
x = material thickness
$X_0$ = radiation length

- Accurate measurements of this radiation length of a device under test (DUT) can improve future tracking reconstruction in detectors.

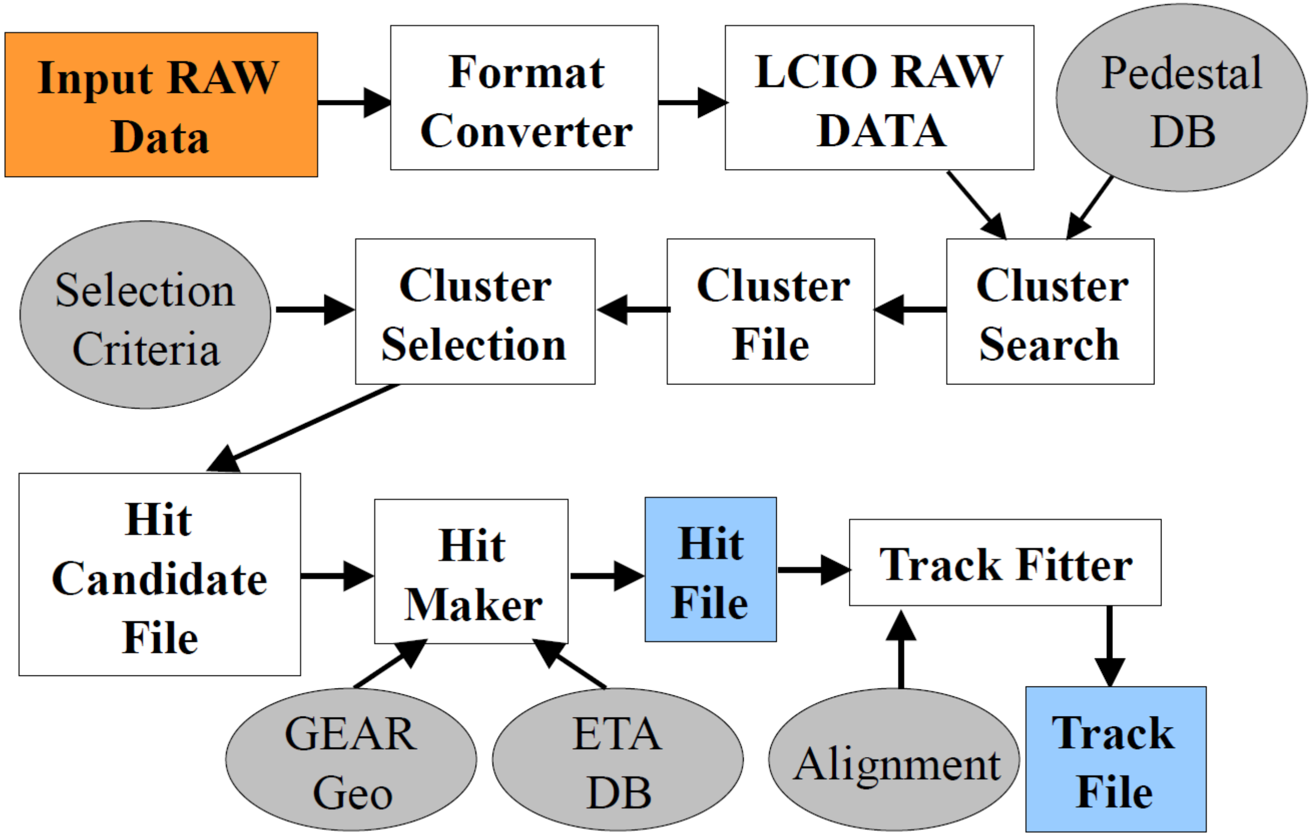
# Experimental set up using DATURA telescope

- Took three sets of data, in three configurations:
  - Front 3 planes close, back 3 planes at 150 mm
  - 20 mm between each plane, front three then DUT, then 1100 mm to the last three planes
  - 150 mm between each plane and DUT
- At 1, 2, 3, 4 and 5 GeV
- With 0, 1, 2, 4 and 8 pieces of >99% pure Aluminium (each piece 1mm thick)



# Analysis – Analysis chain

- Follows the EUTelescope analysis chain , then I add my own processor at the end

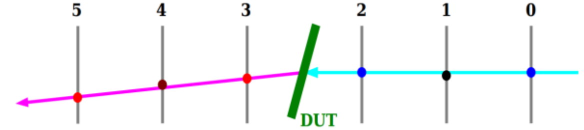


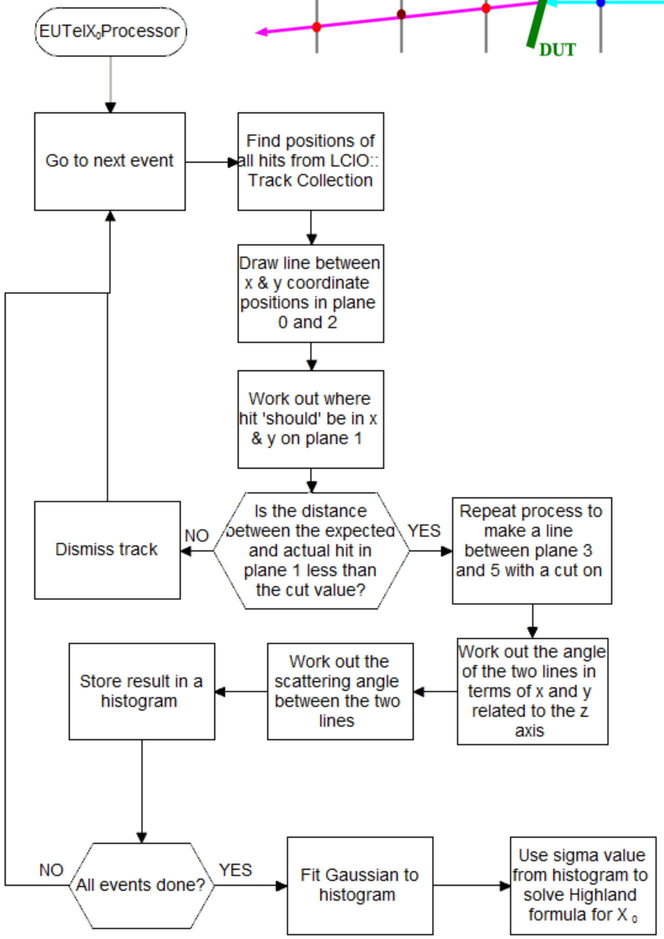

[3] – Diagram from “Introduction to the analysis and reconstruction software of EUDET beam telescope”, *Antonio Bulgheroni*

# Analysis – EUTelX0Processor

- What it currently does:
- Makes straight line fits between planes 0 and 2 and planes 3 and 5.
- Apply a cut to all tracks formed if there is not a hit within a certain radial distance on planes 1 and 4.
- Work out the kink angle of the two straight line tracks.
- Fit a Gaussian to the kink angle, plug that into the Highland formula.
- Get a first estimate value for the radiation length.
- Accuracy is hard to predict

[4] – Image from “Tracking at the test beam”, *Daniel Pitzl*

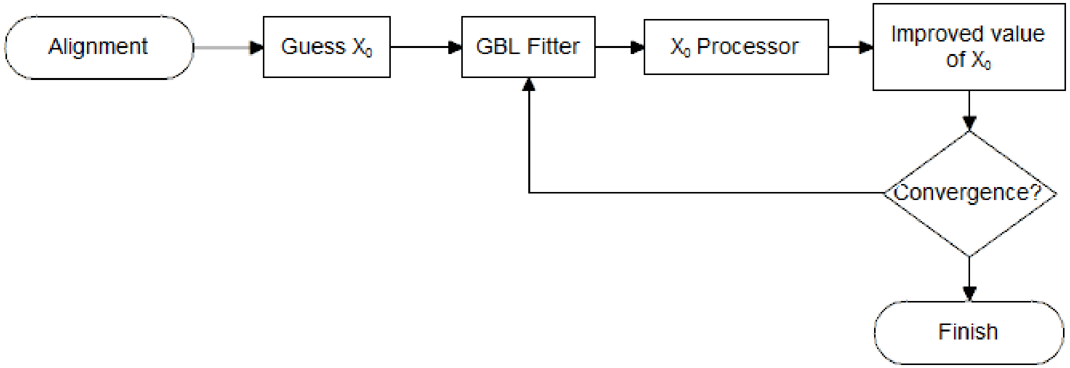


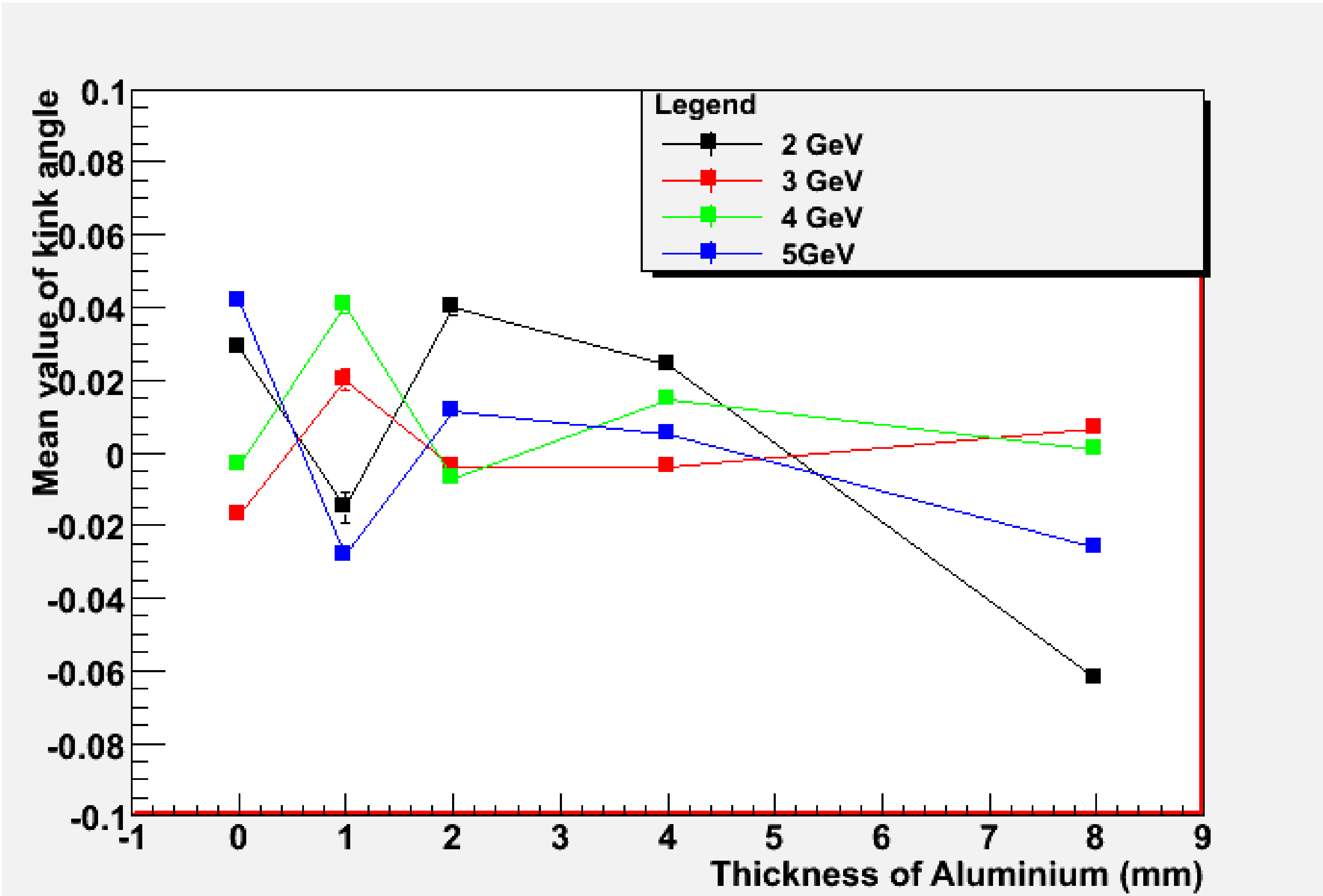
# Analysis – EUTelX0Processor

What it will do in the future:

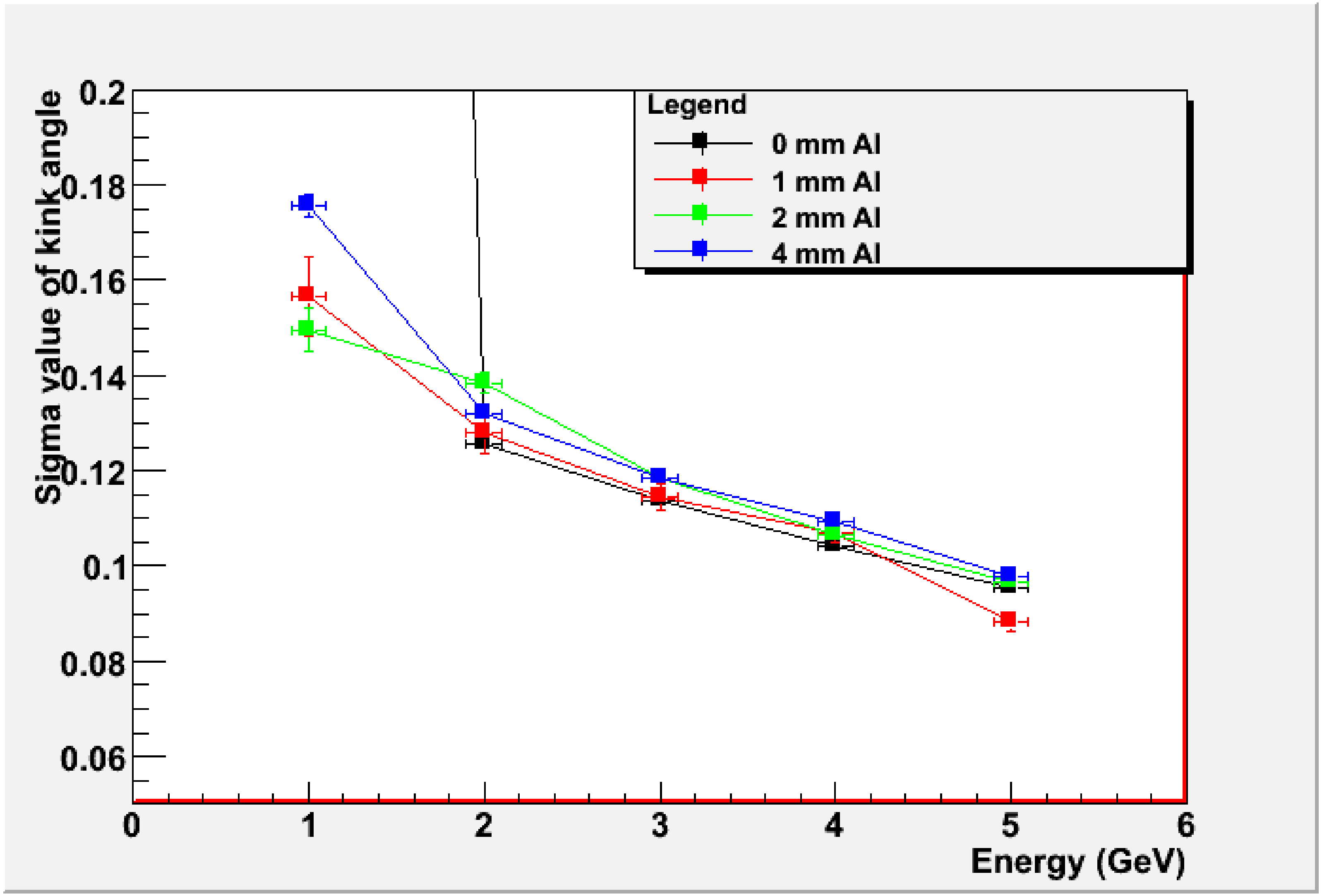
- It will use generalised broken line fitter.
- Much more accurate tracking, but requires knowledge (or estimate) of the radiation length at all points.
- Use an expectation-maximisation algorithm to get a new expected value for the radiation length and use that to find a new and more accurate track. (Based on work of Nadler and Frühwirth).
- Repeat until convergence.



# Results


Legend
2 GeV
3 GeV
4 GeV
5GeV
Mean value of kink angle
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-1
0
1
2
3
4
5
6
7
8
9
Thickness of Aluminium (mm)

# Results



Legend
0 mm Al
1 mm Al
2 mm Al
4 mm Al
Sigma value of kink angle
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0
1
2
3
4
5
6
Energy (GeV)

# Summary and future work

- Taken lots of data.
- Created resolution plots of first data set.
- Have plots of how Gaussian changes with varying energy and material
- Writing the iterative algorithm in EUTelX0Processor.

OUTLOOK

- Work out the radiation length of well known materials.
- Work out the radiation length of some not well known materials.
- Draw a ‘$X_0$ map’ of a complex object.

- Thanks for listening!