Low-Mass Support Structures for Silicon Sensors

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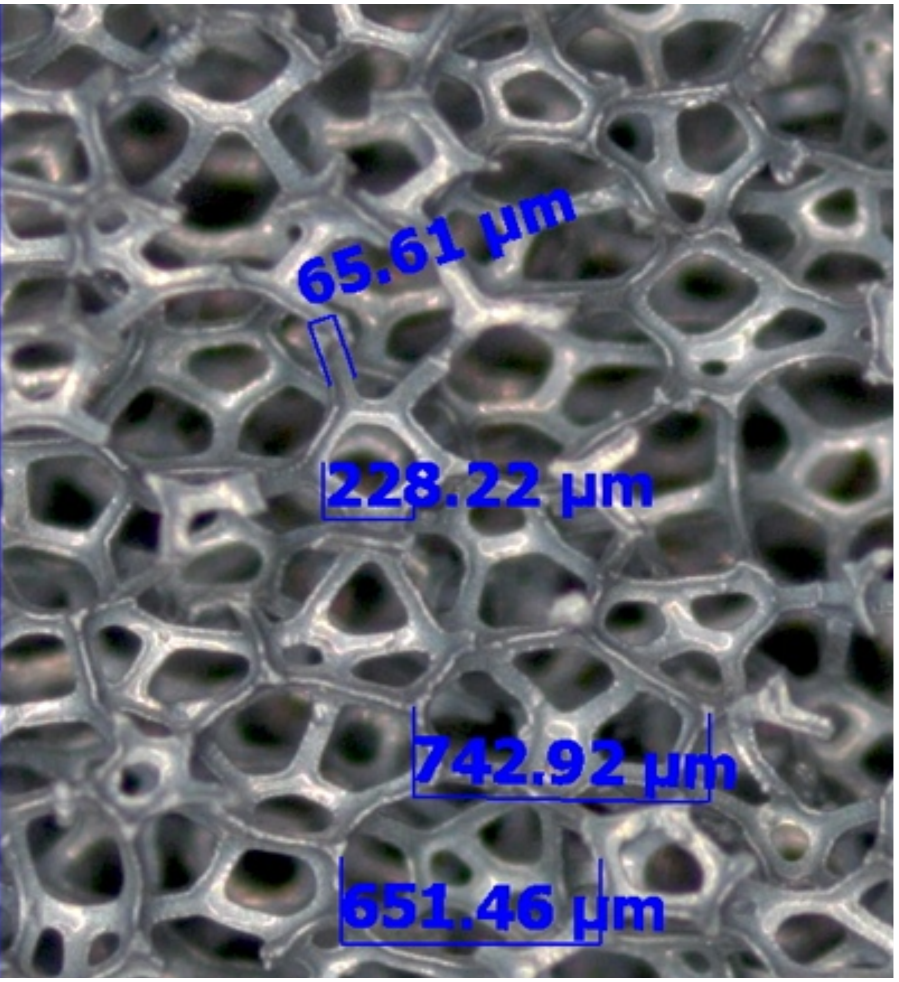
Low-Mass

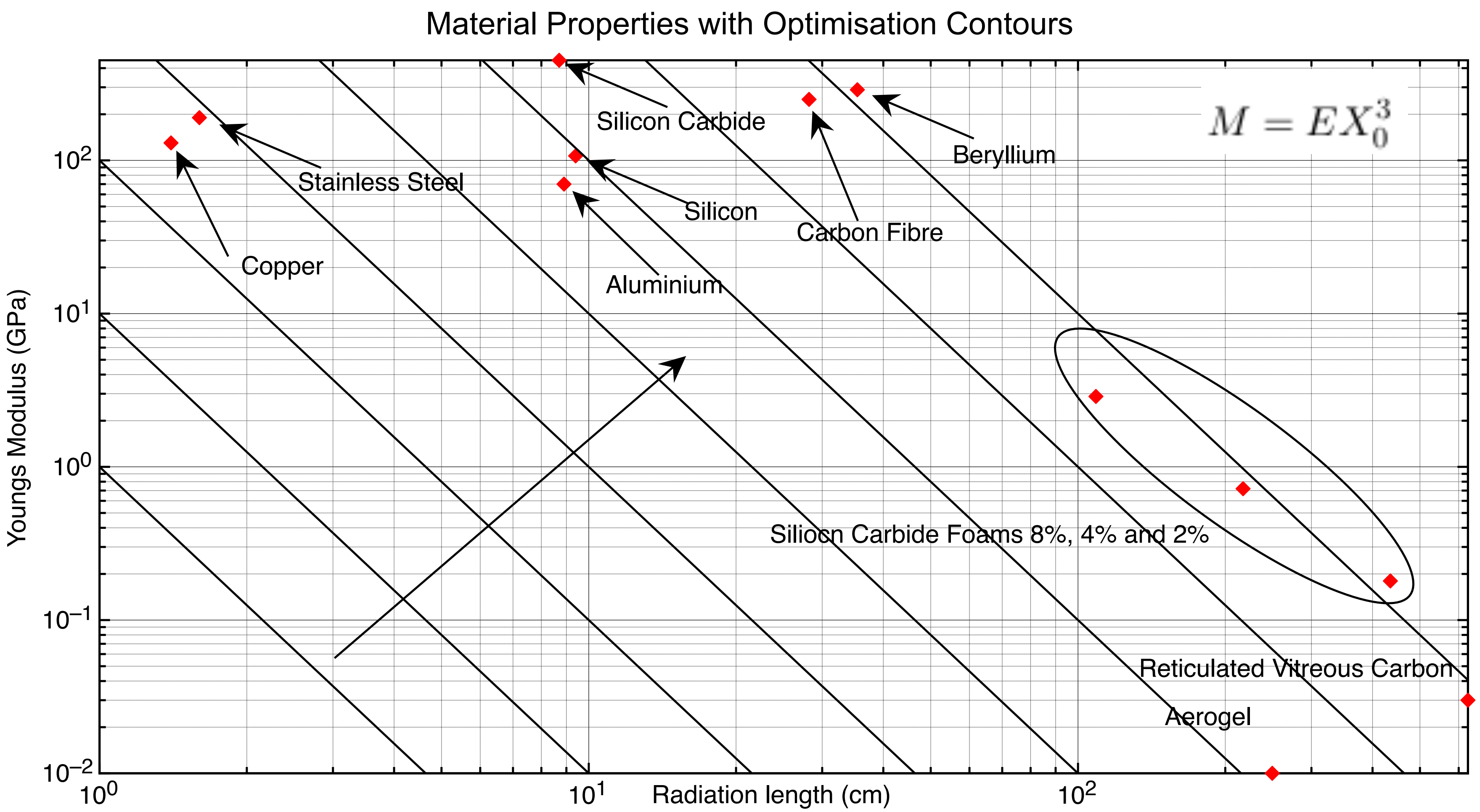
- Collaboration consisting of the Universities of Bristol, Glasgow, Liverpool and STFC RAL
- Study of silicon carbide foam's thermal and mechanical properties for use in future detectors
- Low-Mass has made in-roads into turning this technical ceramic foam into an engineering material by analysing:
  - Machining methods
  - Mechanical properties
  - Characterising of features
  - Module construction
  - All SiC foam vertex detector geometries
  - Thermo-mechanical analysis
  - Tracking performance
  - More realistic simulation of foam

Objectives of a Support Structure

- Ensure stability of sensor in the tracking environment
  - Rigidity of a single module $\propto$ $E \times t^3$
- Minimise material to reduce multiple Coulomb scattering and delta ray production
  1. Reduce thickness of material
  2. Increase the radiation length

Silicon Carbide Foam

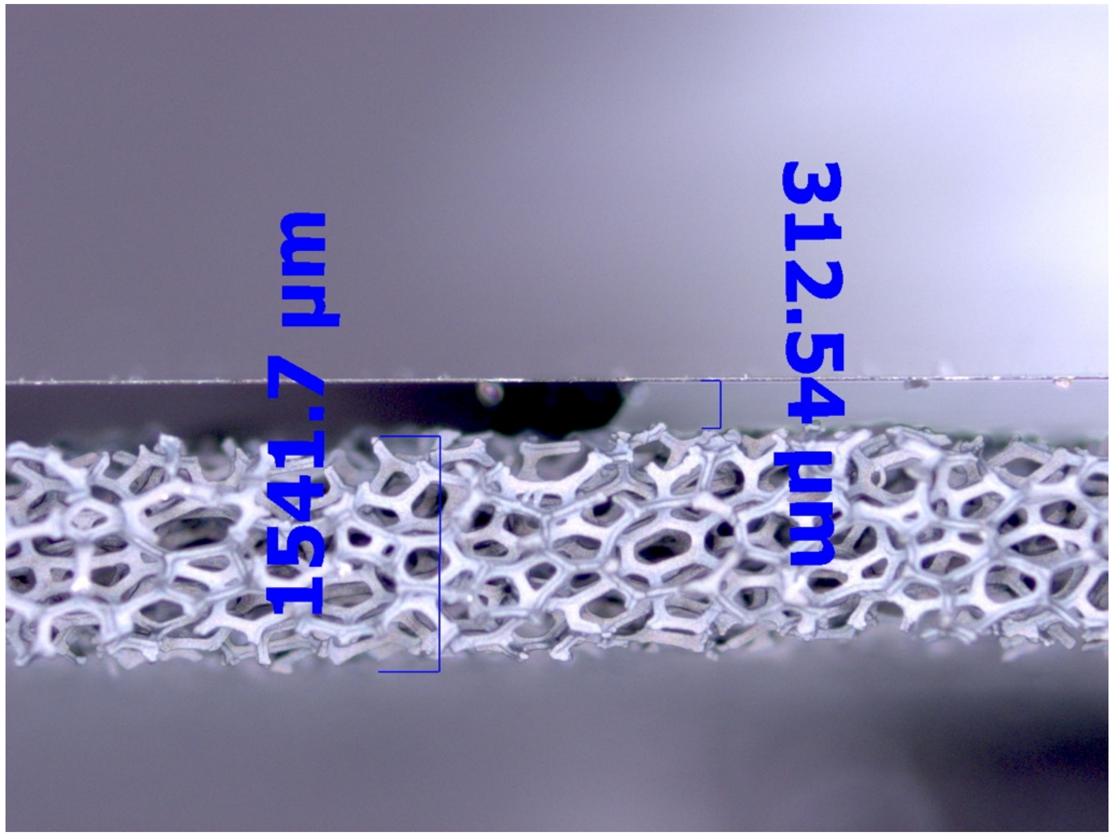


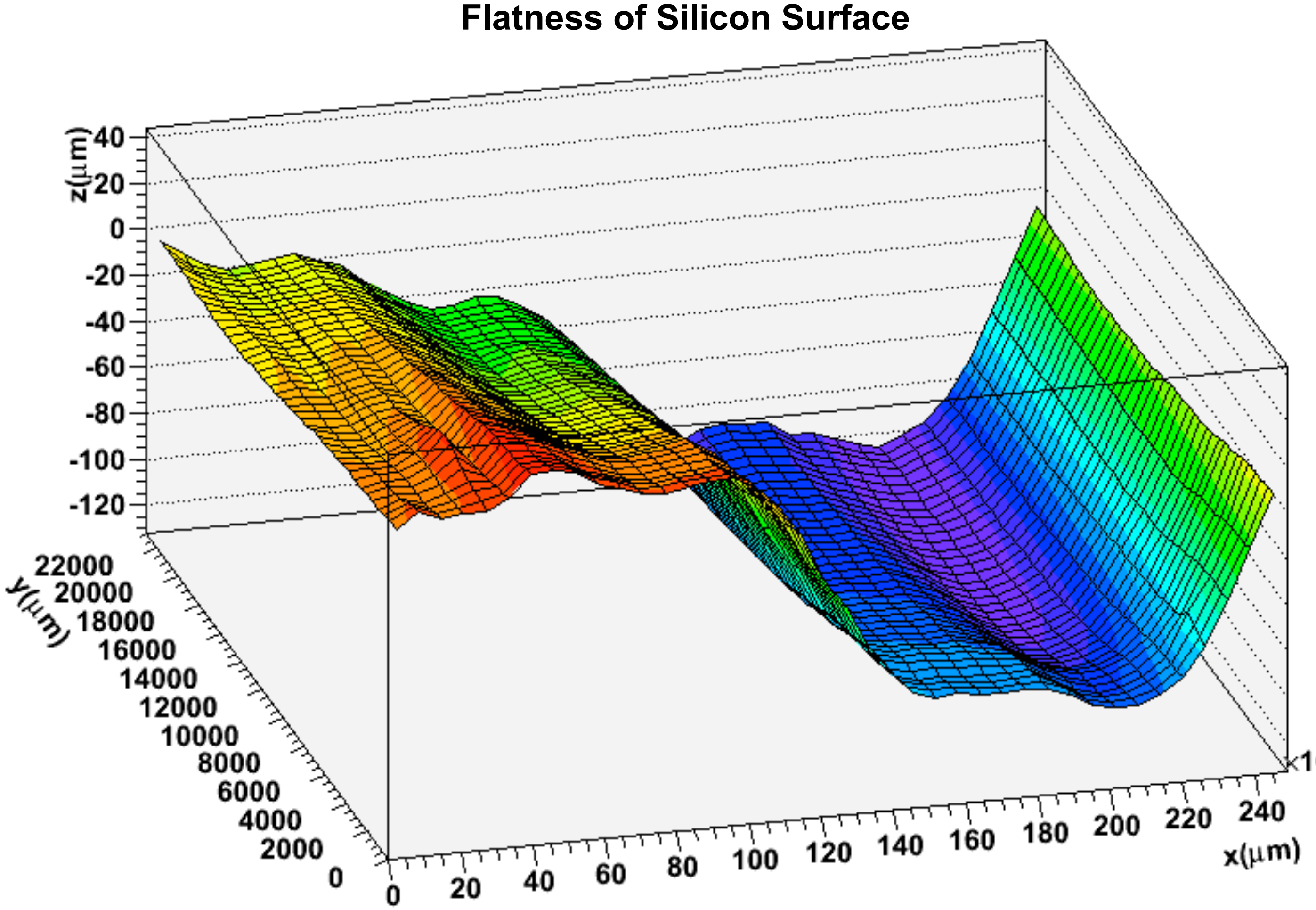


- SiC foam is a cellular structure that is isotropic and homogenous
- Foams can be characterised by 3 properties
  1. Pores per inch
  2. Relative density
  3. Base material
- Maximise Material indices while maintaing stability

Silicon Carbide Modules

- Survey Si surface with a laser micrometer flatness over whole modules of 100-200μm
- Flatness and straightness measured to within ±5μm





- The material budget of 8% SiC with thickness 1.5mm is 0.14%X_0
- Complete module of 3.2% 1.3mm is 0.079%X_0

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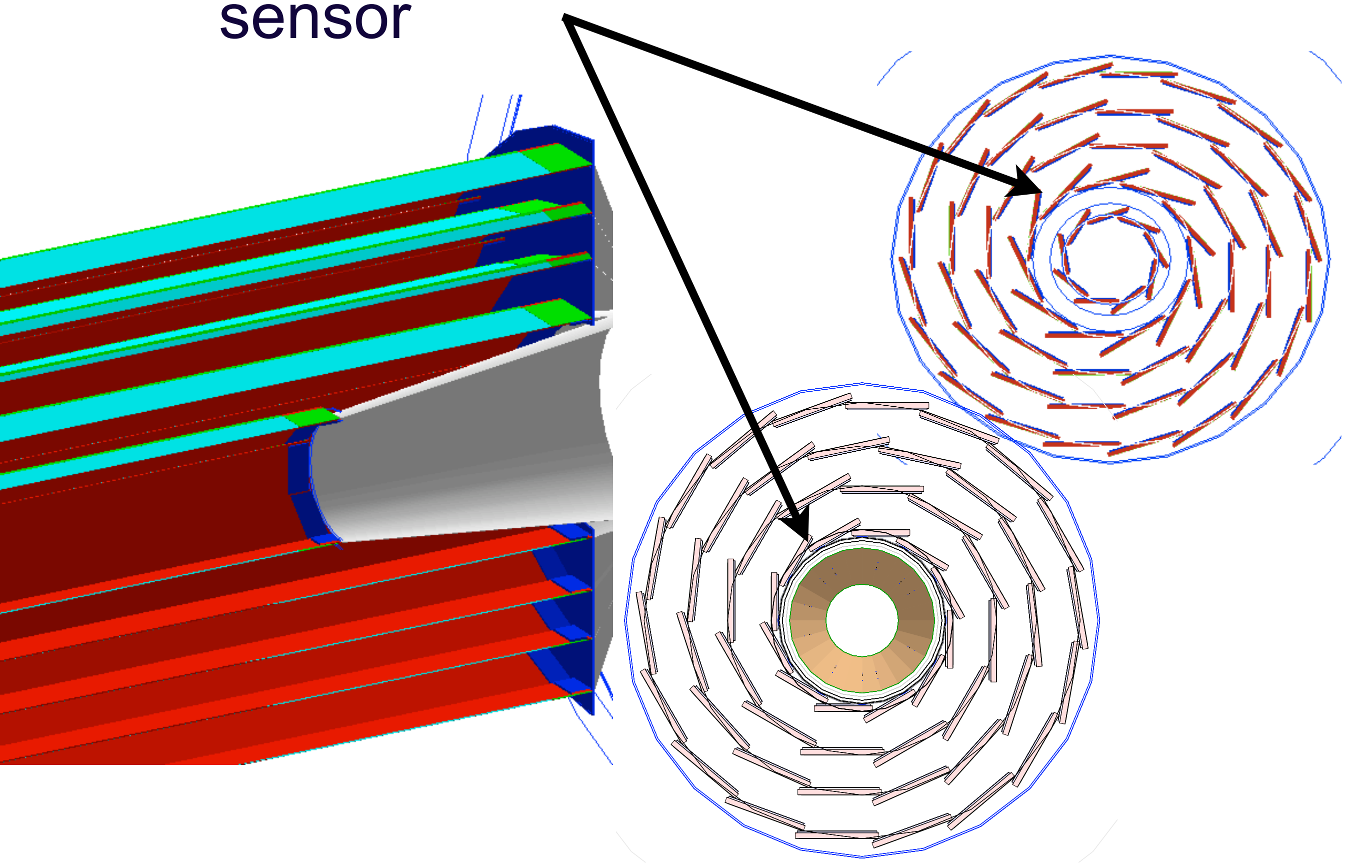
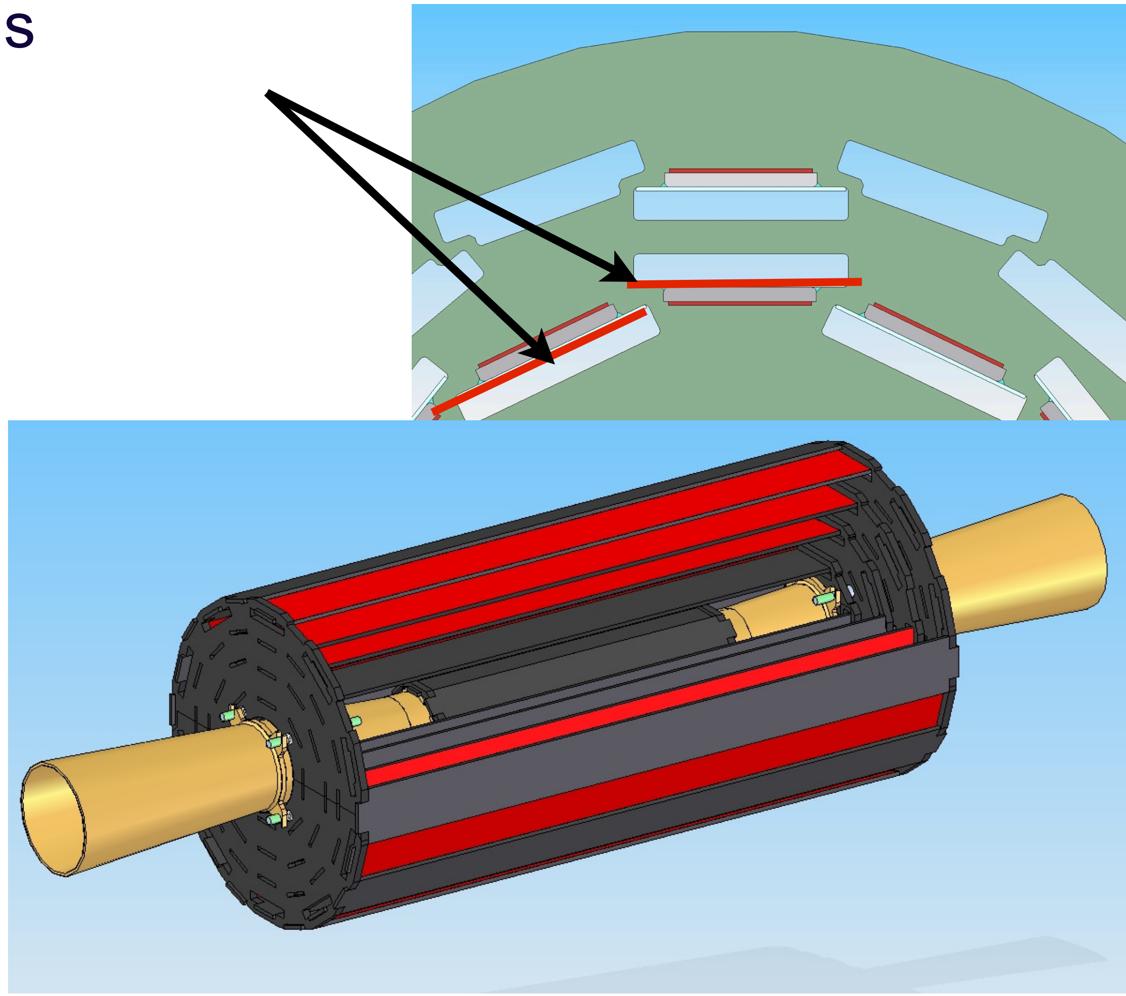
Vertex Detector Geometries

- Nested geometries favour thin ladders allowing overlap between sensitive areas of sensor



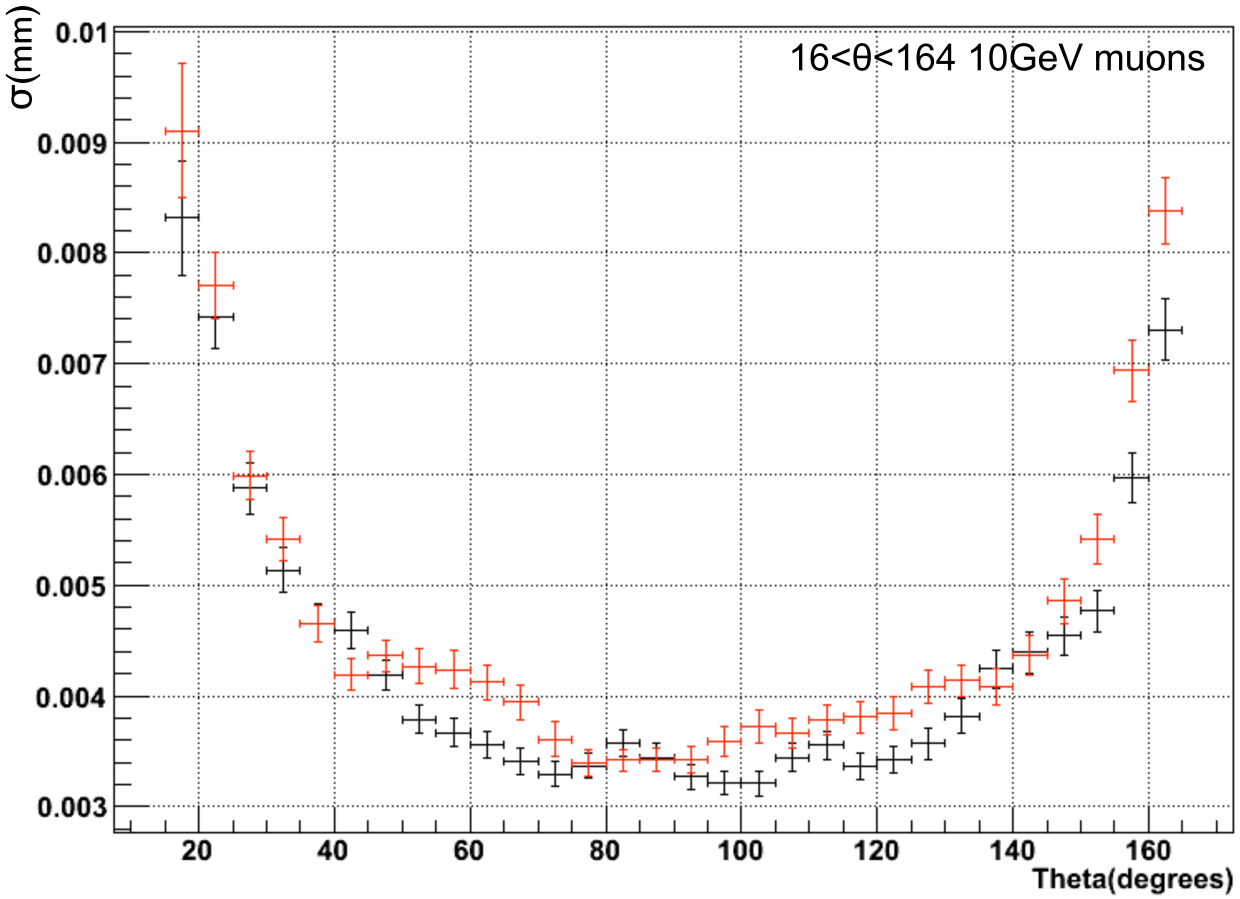
- Need novel design to allow sensors to overlap and keep active region on defined radius



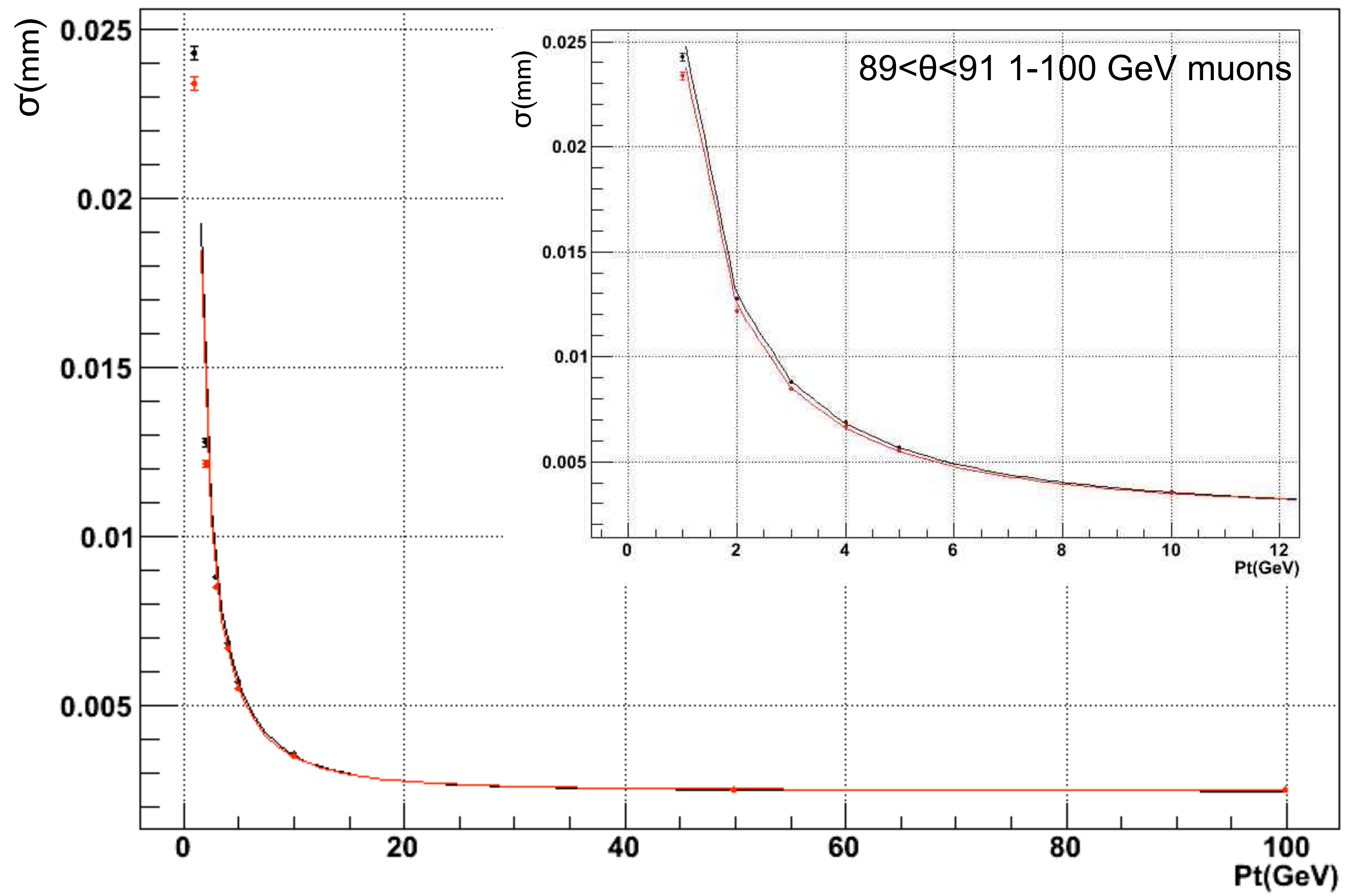
Tracking Performance

- Use impact parameter resolution to compare performance

Impact Parameter Resolution as a Function of Theta



Impact Parameter Resolution as a Function of Pt



- Although not optimised for thick support staves still within 1-5% of ILC baseline over |cosθ|=0.96

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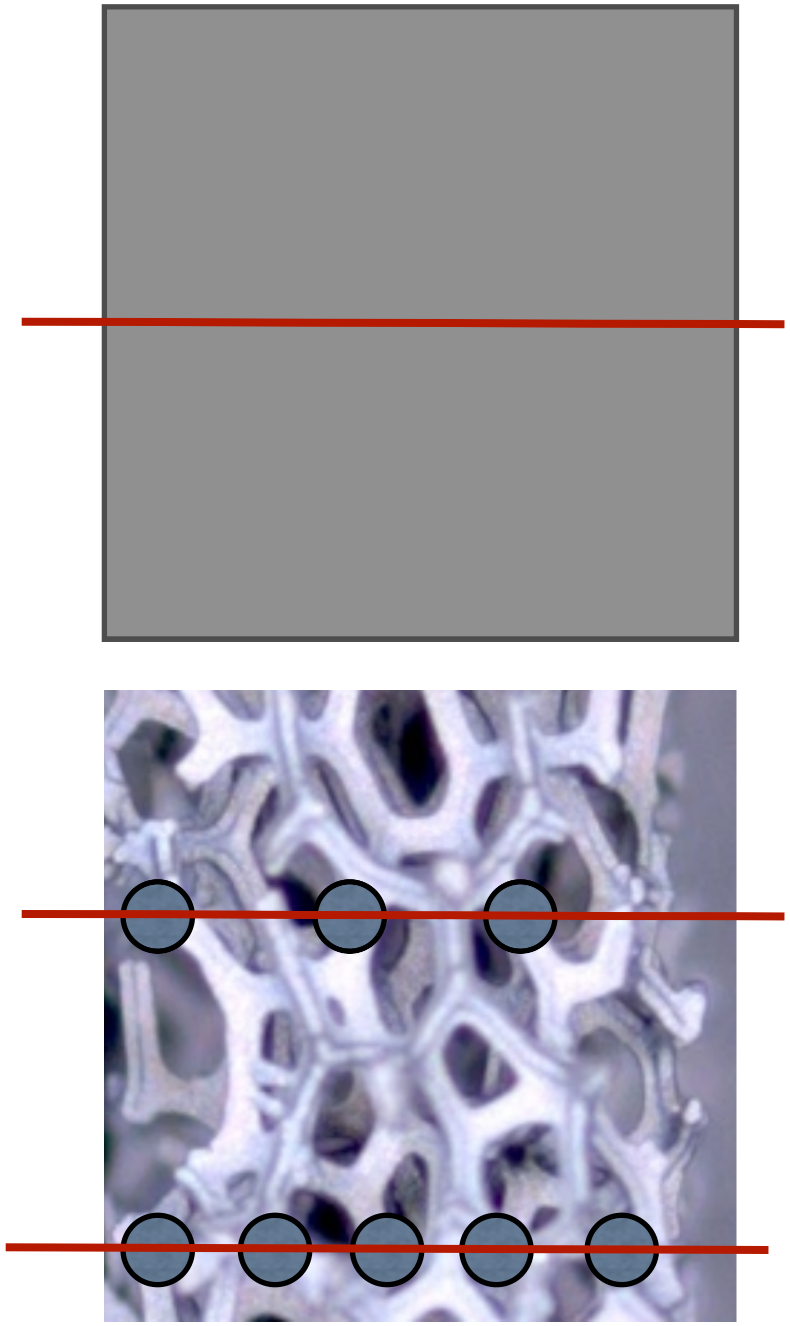
More Realistic Model

- Currently Geant4 simulations model SiC foam as a continuous solid with material averaged over volume
- Given cellular structure particles have a probability of interacting with more material or less material
- To investigate this the number of ligaments traversed is poisson distributed and the resulting scattering distribution analysed
- For a single module most probable number of ligaments is 3



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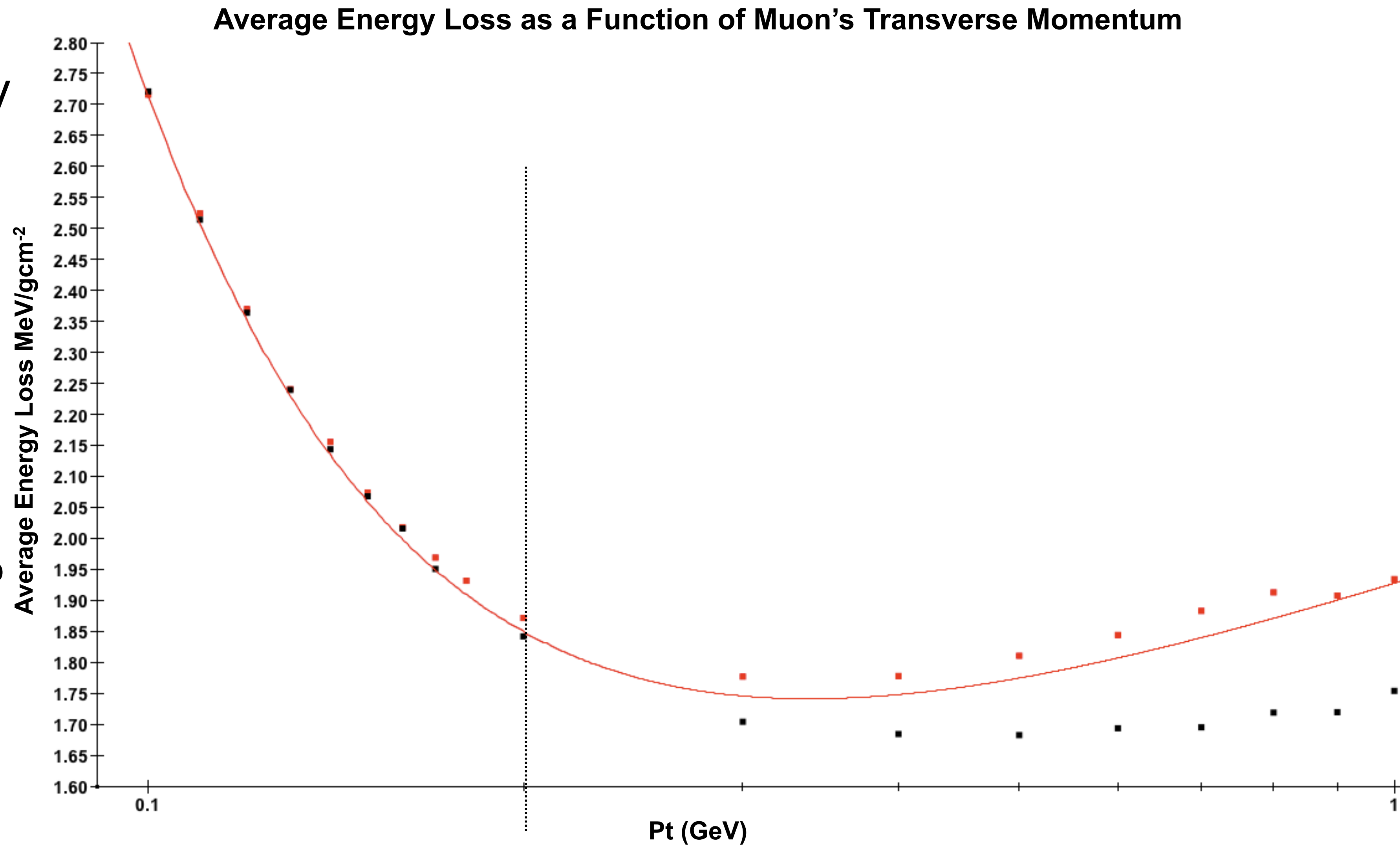
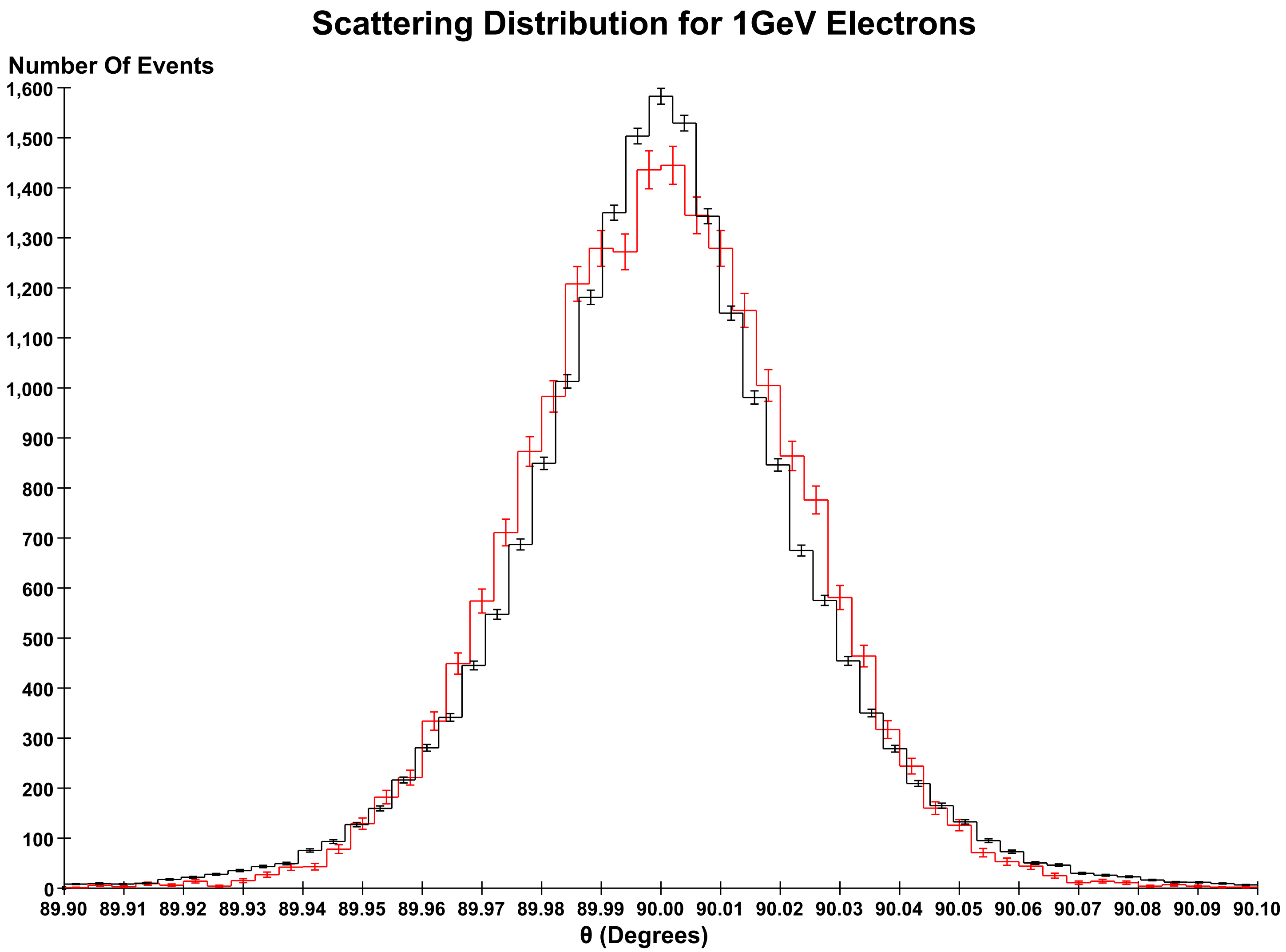
Validating Geant4 Models

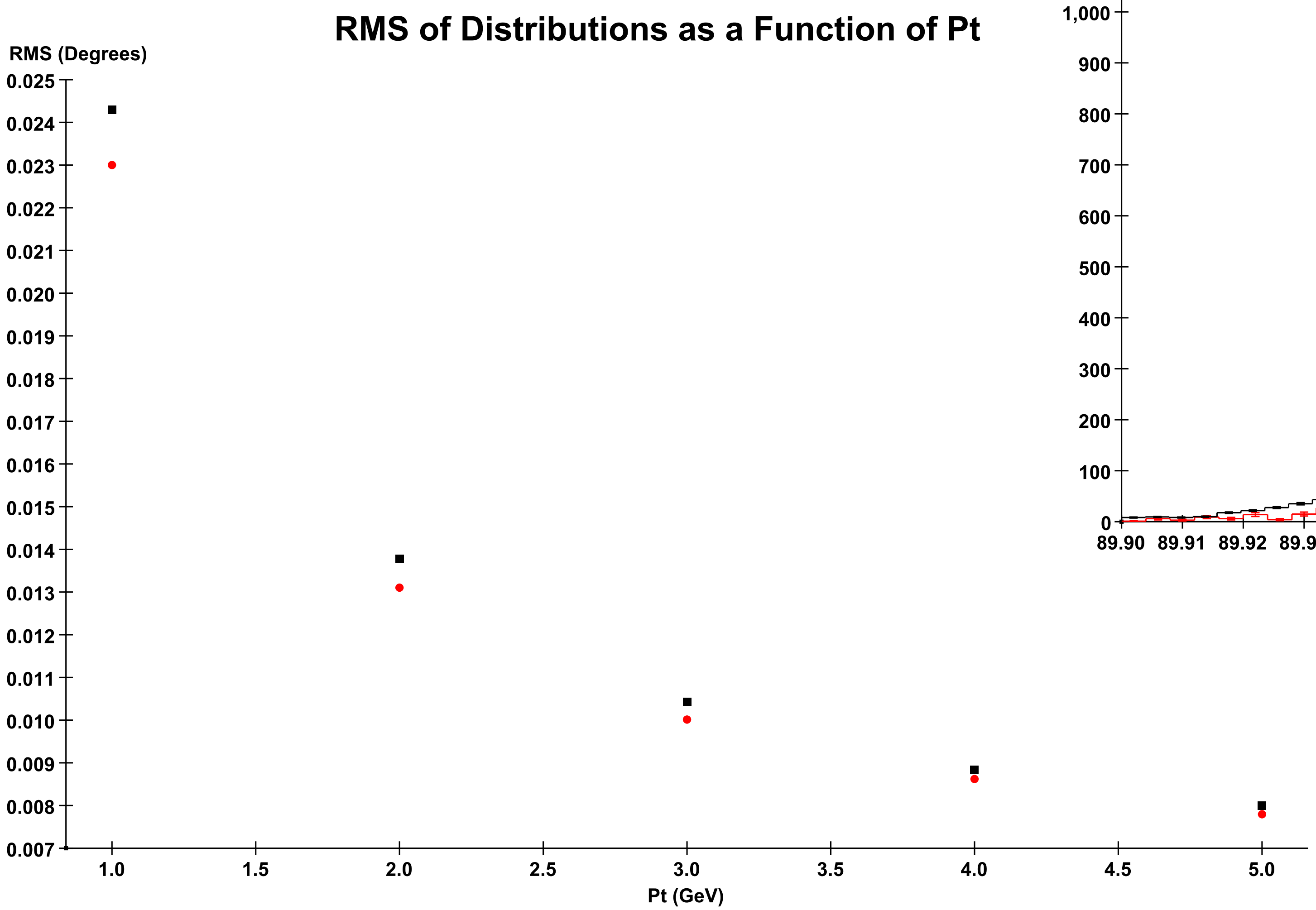
- Model behaviour checked by analysing average energy loss
- When the density correction term (δ) is 0 the energy loss for both models is the same
- δ = 0 in the range 0.1 - 0.2 where the difference is < 1%
- For 0.2 - 1 the density correction term splits the dE/dx of the two models



Scattering Distributions

- Probability of moving through more material or less material than average leads to differences in distributions





- The difference in RMS for the different models at 5GeV is < 1%

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Conclusions and Future Plans

- We have proven SiC foam can be used for construction of single modules
- From this we have enough understanding to build complete structures and test them
- The unoptimised impact parameter resolution is comparable to CFRP support structures that are mechanically unproven
- Scattering distributions are measurably different for low momentum tracks
- Models will be tested in test beam analysis
- Whether this would effect the tracking performance would then need to be investigated depending on the outcome
- Material should be seriously considered when designing a tracking system