

CM31: Multiple Scattering in GEANT4

Timothy Carlisle
University of Oxford

Intro (1)

- Calc. multiple scattering using **PDG** approx.: $\theta_{plane}^{rms} = \frac{13.6\text{MeV}}{\beta c p} z \sqrt{x/X_0} [1 + 0.038 \ln(x/X_0)]$

- Used in the cooling formula:

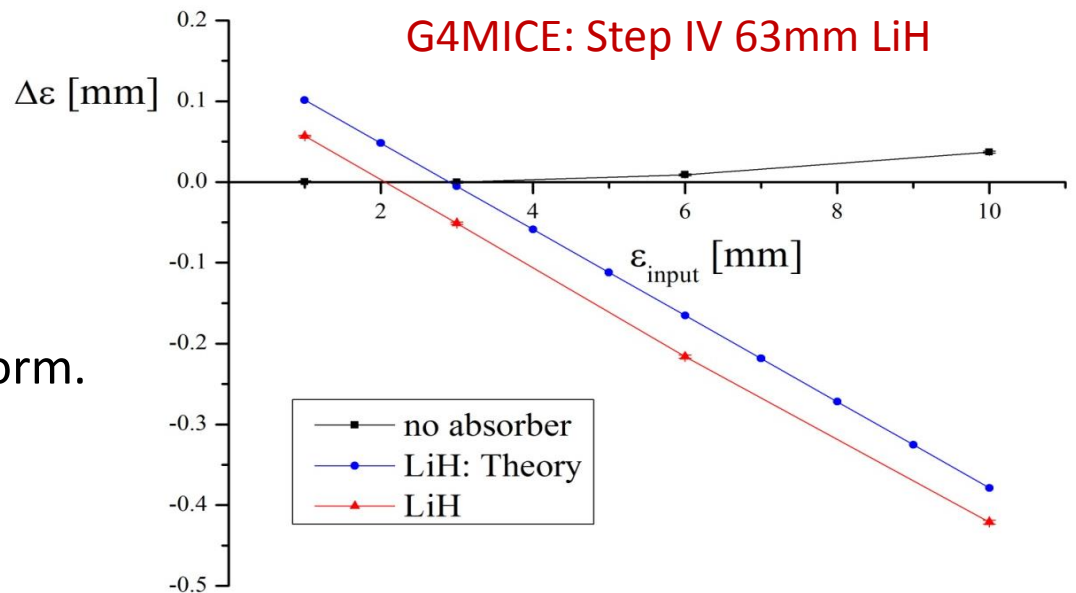
$$\frac{d\varepsilon_n}{dz} = \frac{-\varepsilon_n}{\beta^2 E} \left\langle \frac{dE}{dX} \right\rangle + \frac{\beta_t (0.014 \text{ GeV})^2}{2\beta^3 E m_\mu X_0}$$

→ Predict **Equilibrium emittance** ε_0

- Characterize cooling performance of a material
- **Measure** in **Step IV**

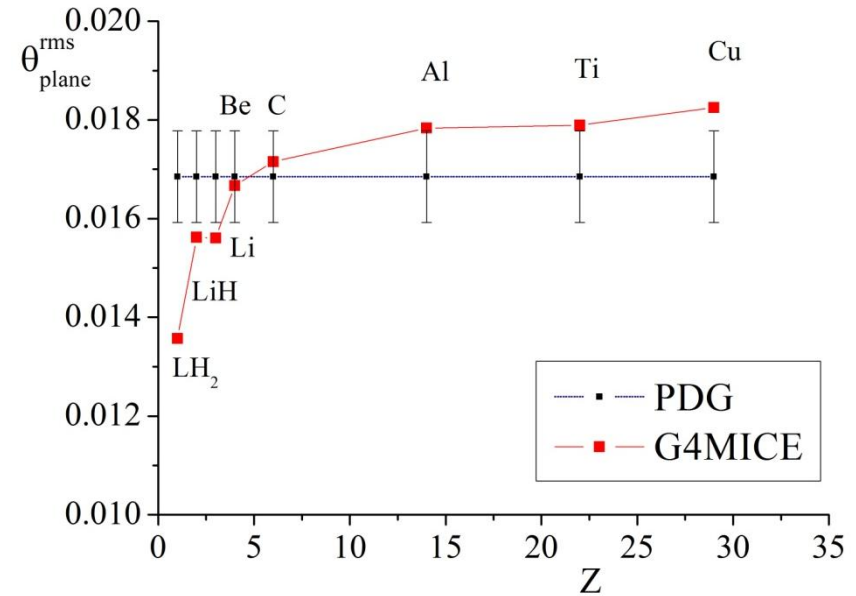
- **However**

ε_0 in G4MICE \neq cooling form.

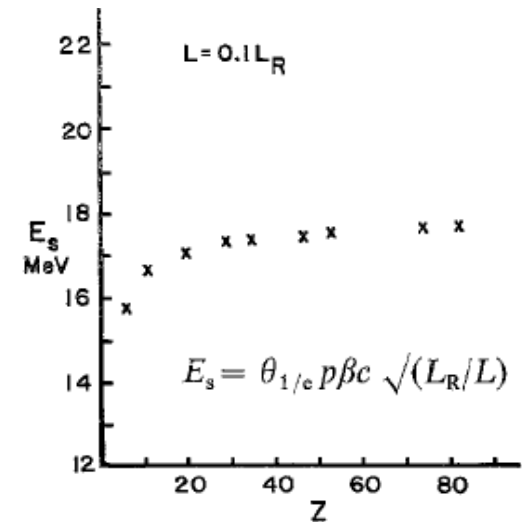


Intro (2)

- Simple PDG approx. unsuitable
- x/X_0 scaling poor at low Z
- e^- screening calc. increasingly inaccurate



- Seen previously – see Highland.
- Geant4/G4MICE
 - Uses **Lewis Theory**
 - parameterizes distributions



Step IV

- Measure ε_0 in different materials
- Check results are consistent with theory – **how?**

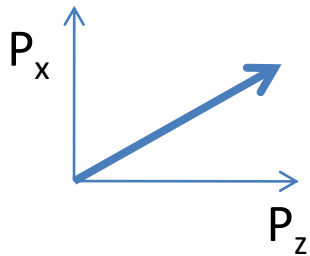
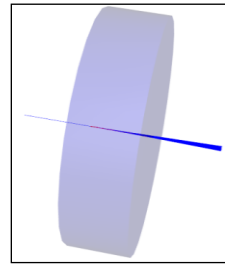
→ Compare with G4MICE

- GEANT4.9.2

Z	X_0		x [cm]
1	63.04	LH ₂	57.61
3	82.78	Li	10.06
4	65.19	Be	2.29
6	42.7	C	1.39
2.00	79.62	LiH	6.30

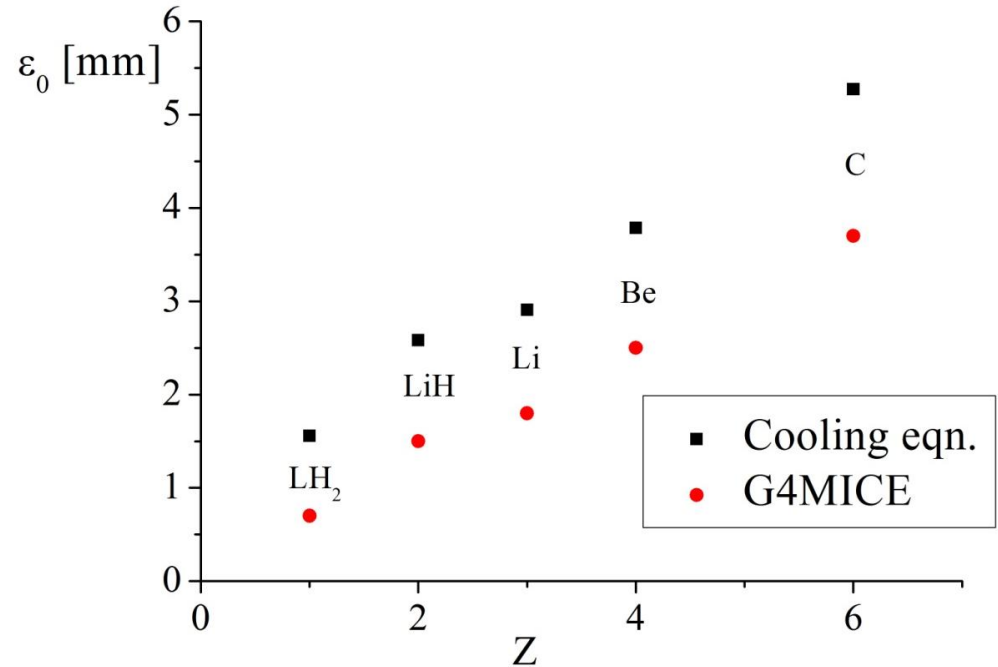
G4MICE

$N_\mu = 100,000$
pencil beam on axis
no fields



$$\theta_x = a \tan(P_x / P_z)$$

$$\theta_{plane}^{rms} = \sigma_x$$

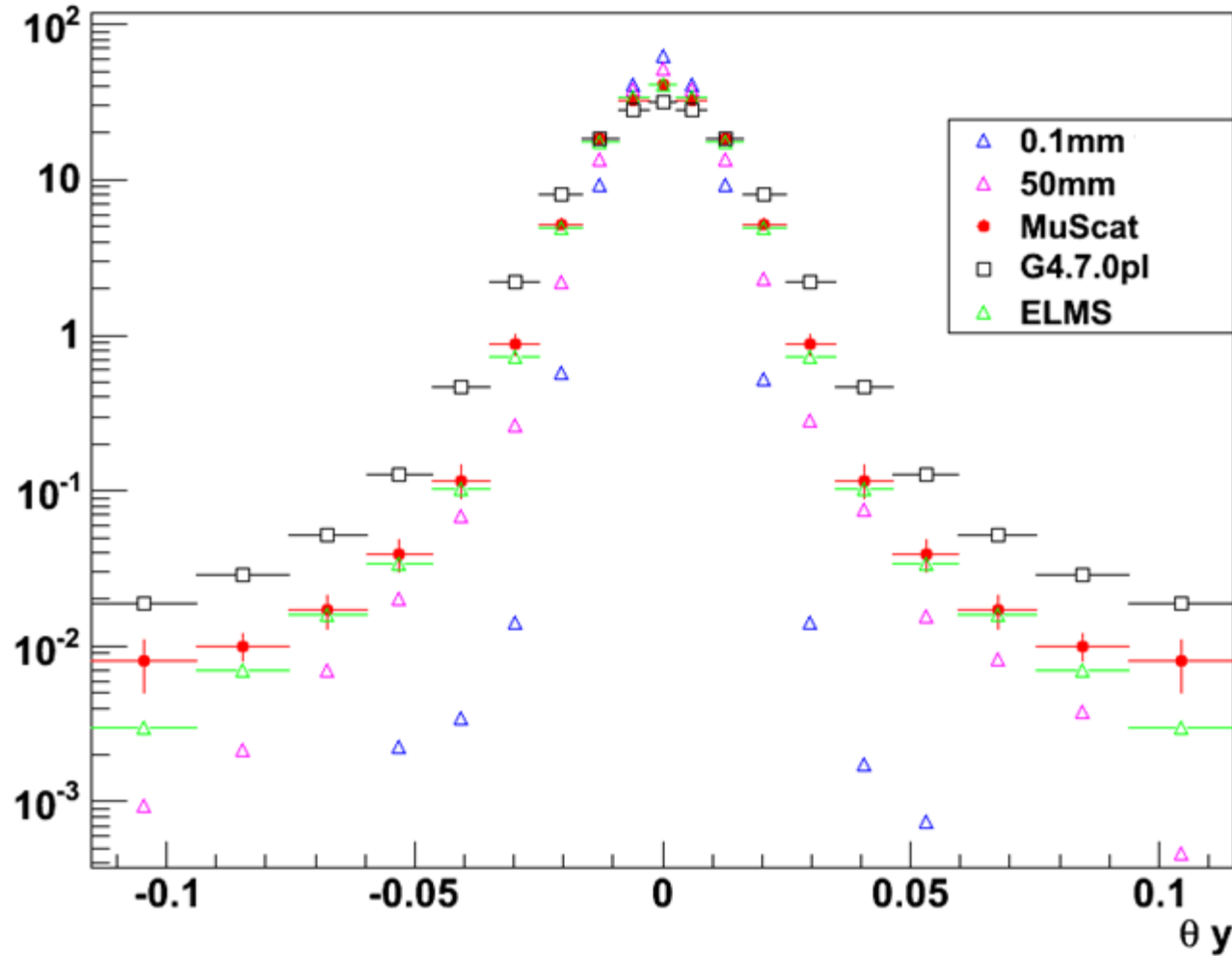


GEANT4

i.e. the underlying physics processes within G4MICE/MAUS

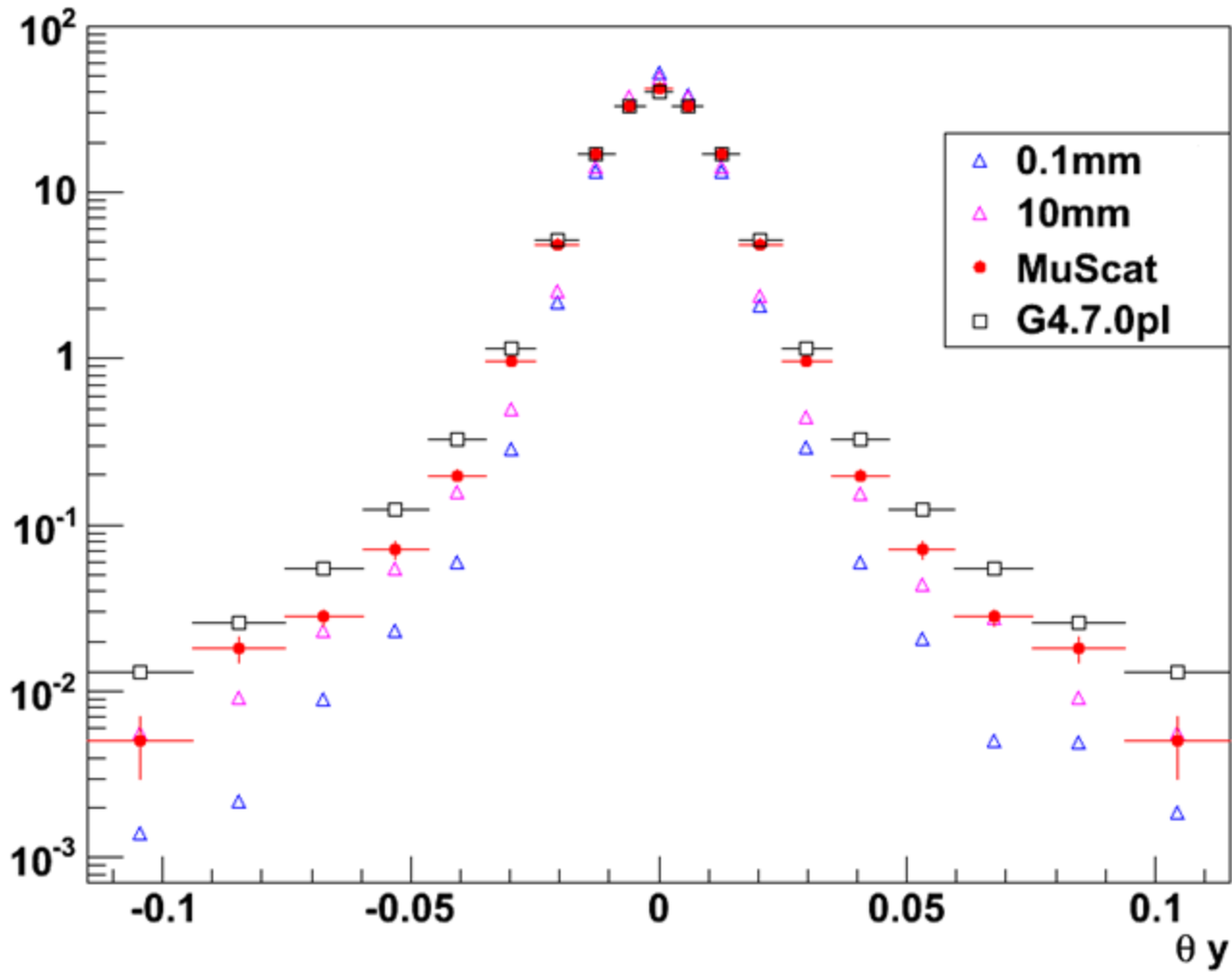
- But....**how good is GEANT4?**
 - Check with [MuScat](#) results.
- Physics processes should be largely indep. of max. Step Size (SS)...
 - Set by a datacard in G4MICE.
- 15.9 cm **LH₂**
 - Compare with **ELMS** code
- 0.15 cm **Aluminium**

15.9 cm LH₂

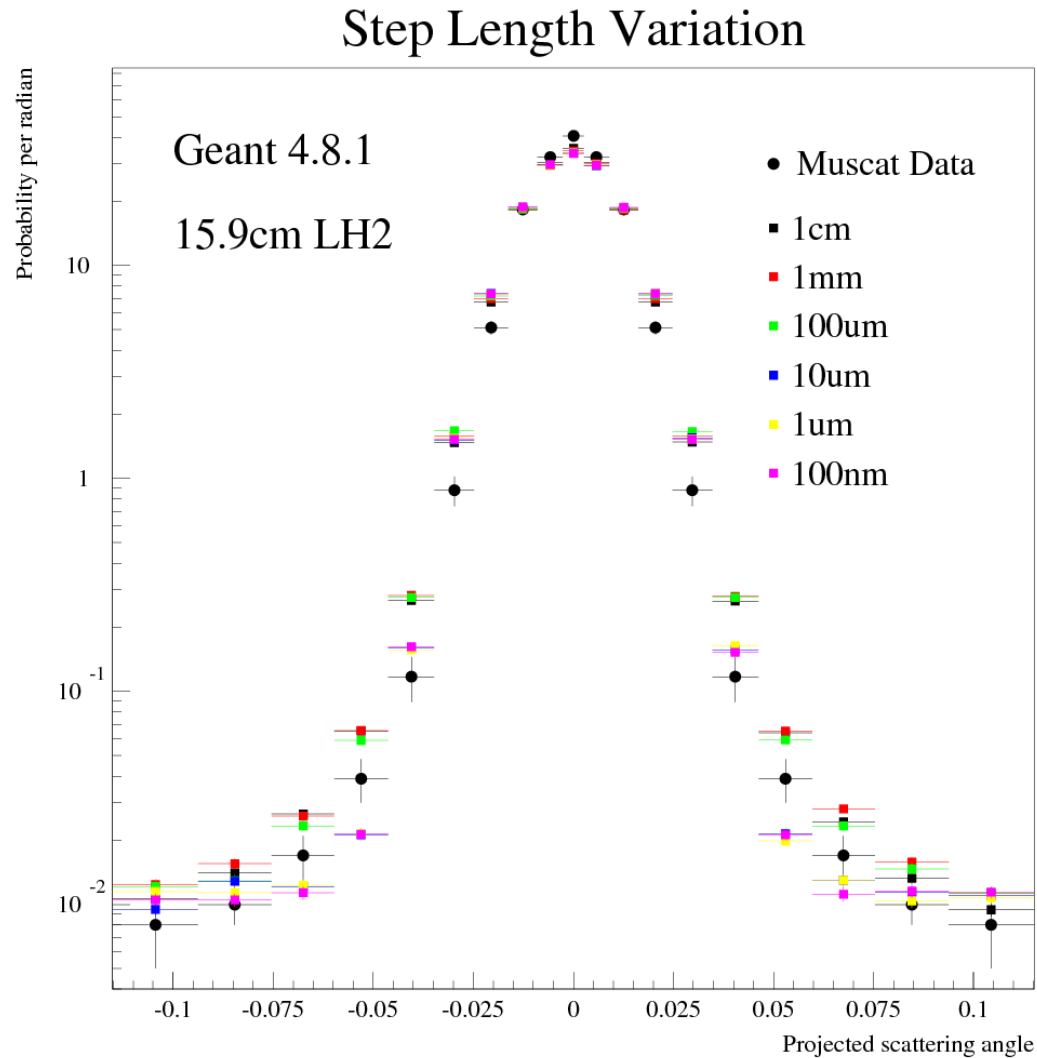


Step Size

0.15 cm Aluminium



Existing studies in better agreement...



Summary

- **Step IV** will measure ε_0 in various materials.
- Standard PDG approx. useless to predict ε_0
 - Need a **strong handle** on ε_0 prior to Step IV running!
- Multiple Scattering in G4MICE
 - V. strong Step Size dependency, **not understood**.
 - Doesn't correlate with Malcolm E's findings...
- Lots of additional parameters in GEANT4
 - Not directly controlled through G4MICE.
 - Dig deeper into GEANT4? → nuts & bolts of physics processes...
- Large discrepancy with **MuScat**
- Compare G4MICE with **Monte Carlo** calc.?