Step IV Studies

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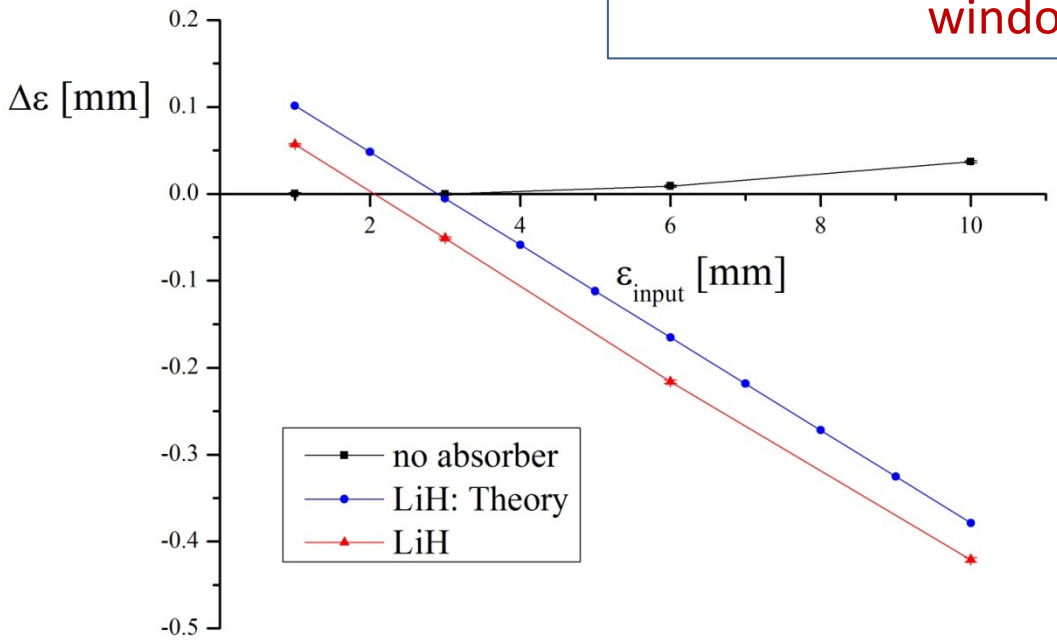
Intro.

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

- CM28 – Step III vs Step IV
- Cooling formula & G4MICE disagree on ε_0
  - Also observed in ICOOL (note #199 – Marco/John Cobb)

Step IV, 63mm LiH + AFC inc. windows

[from CM28]



- Cooling formula assumes Gaussian approximation:

PDG:

From **Moliere**

$$\theta_{plane}^{rms} = \frac{13.6\,\mathrm{MeV}}{\beta cp} z\sqrt{x/X_0}\left[1 + 0.038\,\ln(x/X_0)\right]$$

G4MICE→GEANT4:

uses **Lewis Theory**,

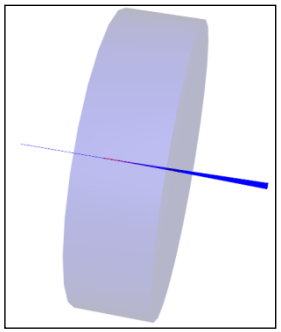
"develops a theory valid for any angle by using Legendre polynomials and then goes over into the small Angle"

...simple then!

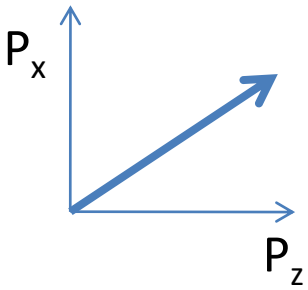
- Compare PDG with scattering in G4MICE.

G4MICE:

N_μ=10,000
pencil beam on axis
no fields

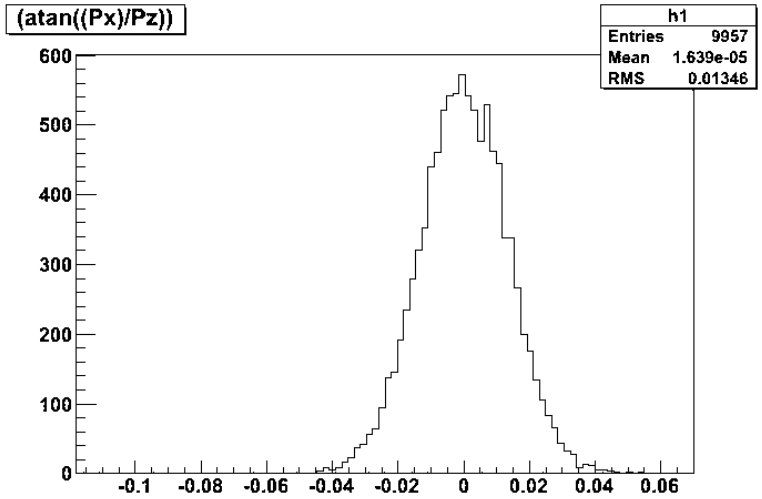


58cm LH_2



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

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

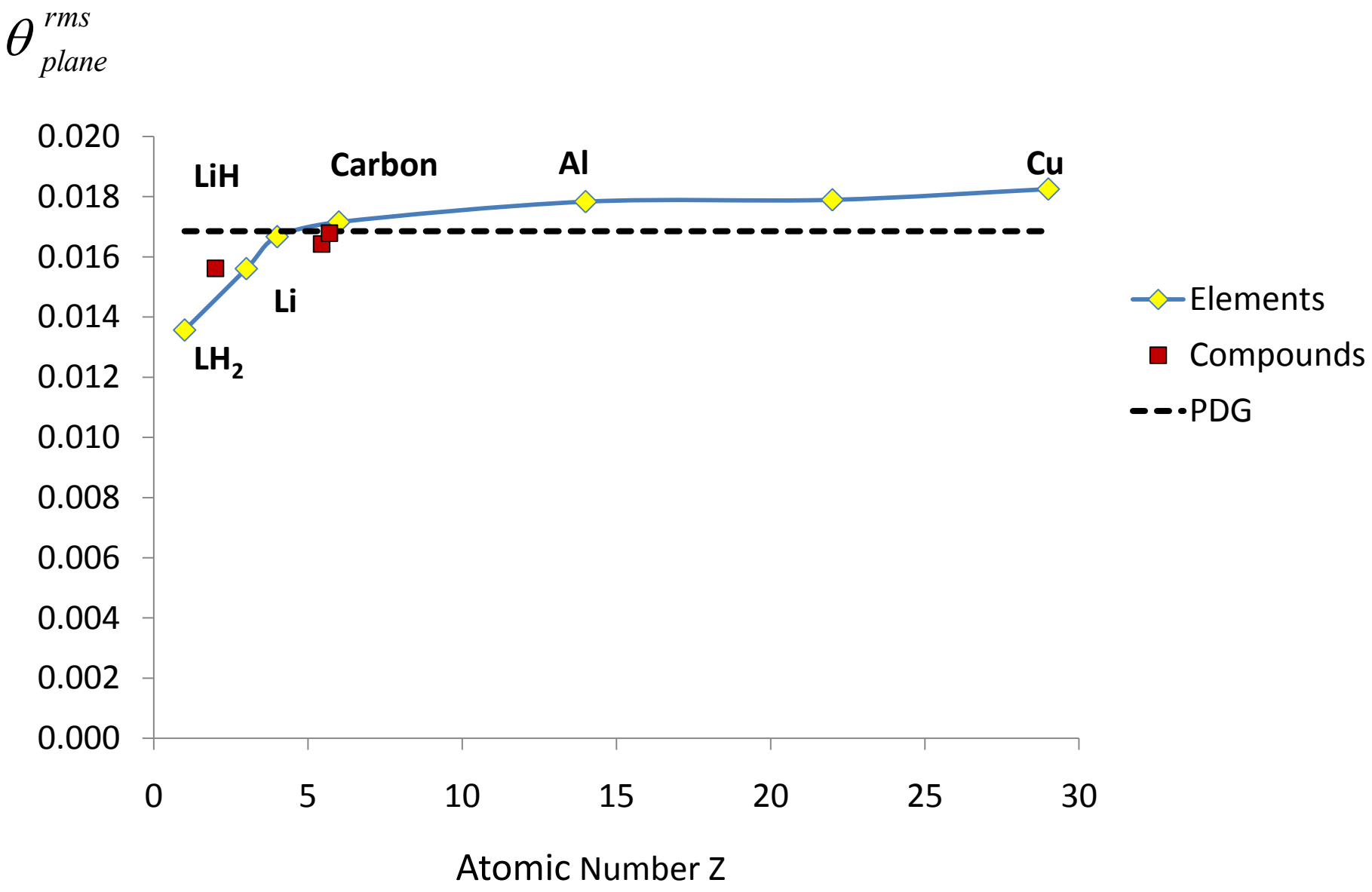


- Absorbers in Step IV scaled so ΔE = const.

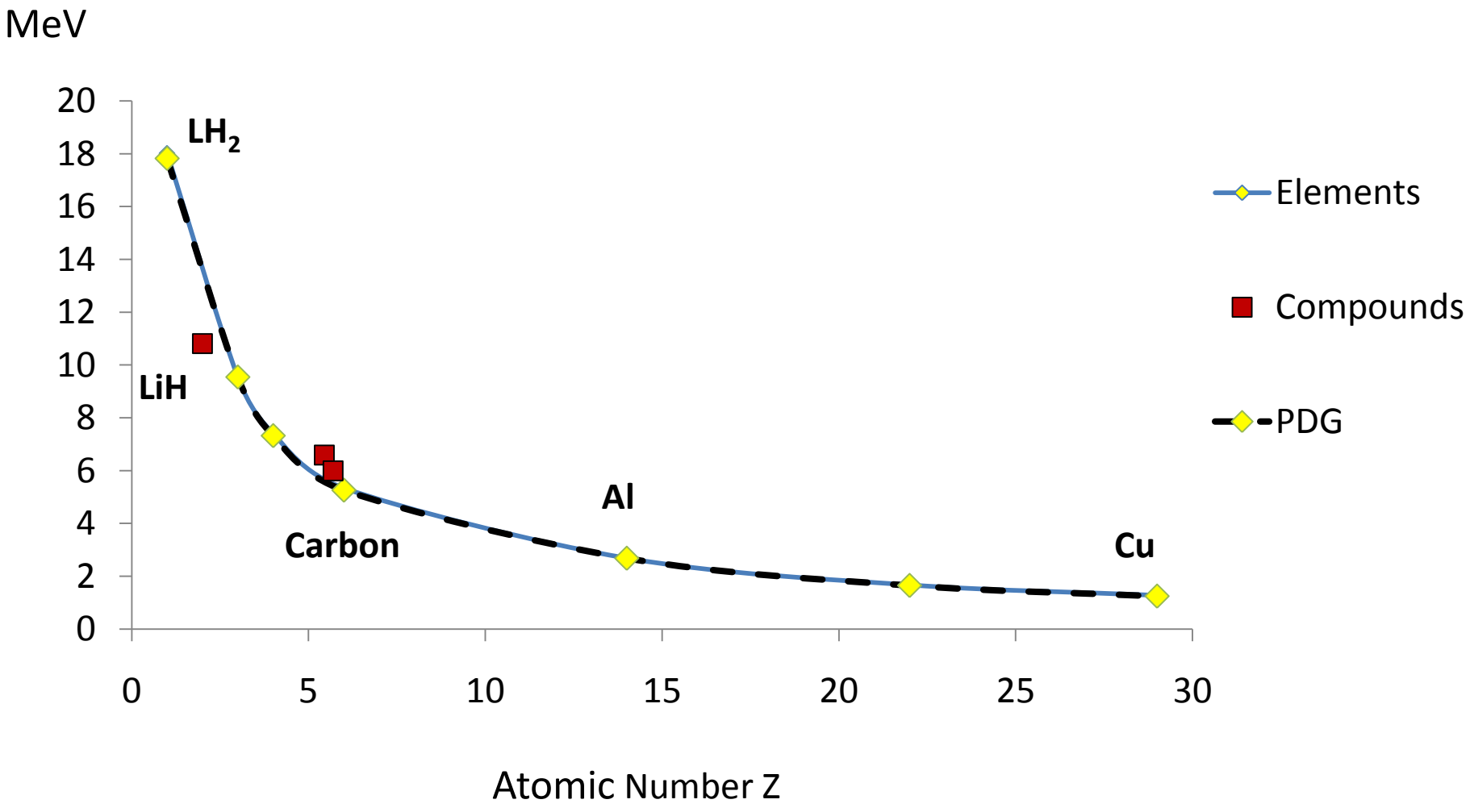
- **Instead** fix the scattering angle → x/X_0 = const.
  → **θ scaled to 63mm LiH**

Z	X_o		*x* [cm]
1	63.04	LH2	57.61
3	82.78	Li	10.06
4	65.19	Be	2.29
6	42.7	C	1.39
14	24.01	Al	0.58
22	16.16	Ti	0.23
29	12.86	Cu	0.09
2.00	79.62	LiH	6.30
5.44	44.77	Polyethylene (C_2H_4)	3.09
5.69	43.79	Polystyrene (C_8H_8)	2.68

Scattering Angle



Energy Loss


MeV
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
LH_2
LiH
Carbon
Al
Cu
Elements
Compounds
PDG
Atomic Number Z

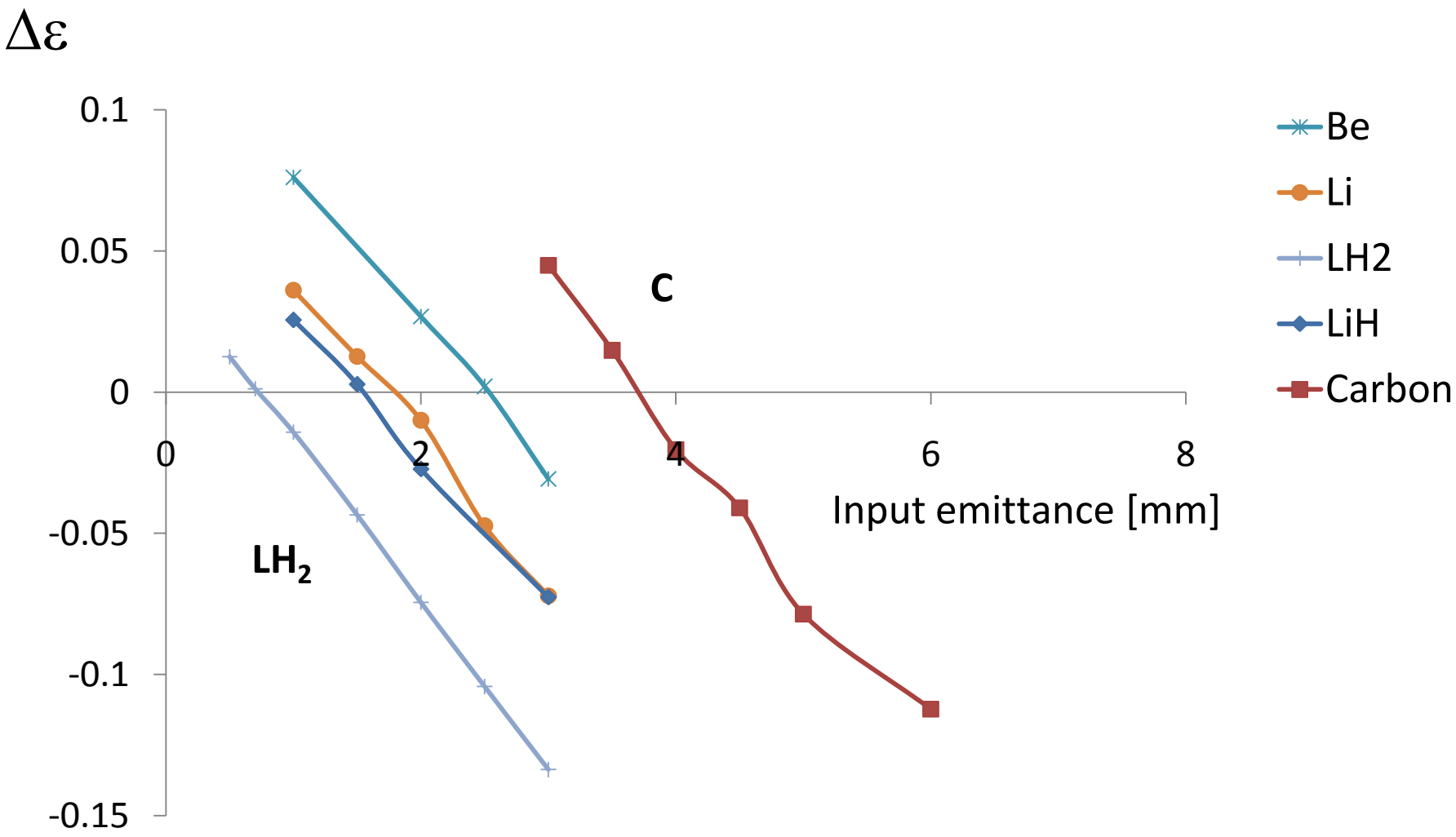
- Scattering isn't so simple to predict it seems.
- Energy Loss seems fine however.
- MICE acceptance limited to $\varepsilon_{input} < 10\,mm$
  - i.e. measure ε_0 up to Carbon (maybe Aluminium)

- Find ε_0 in G4MICE in different materials, for:

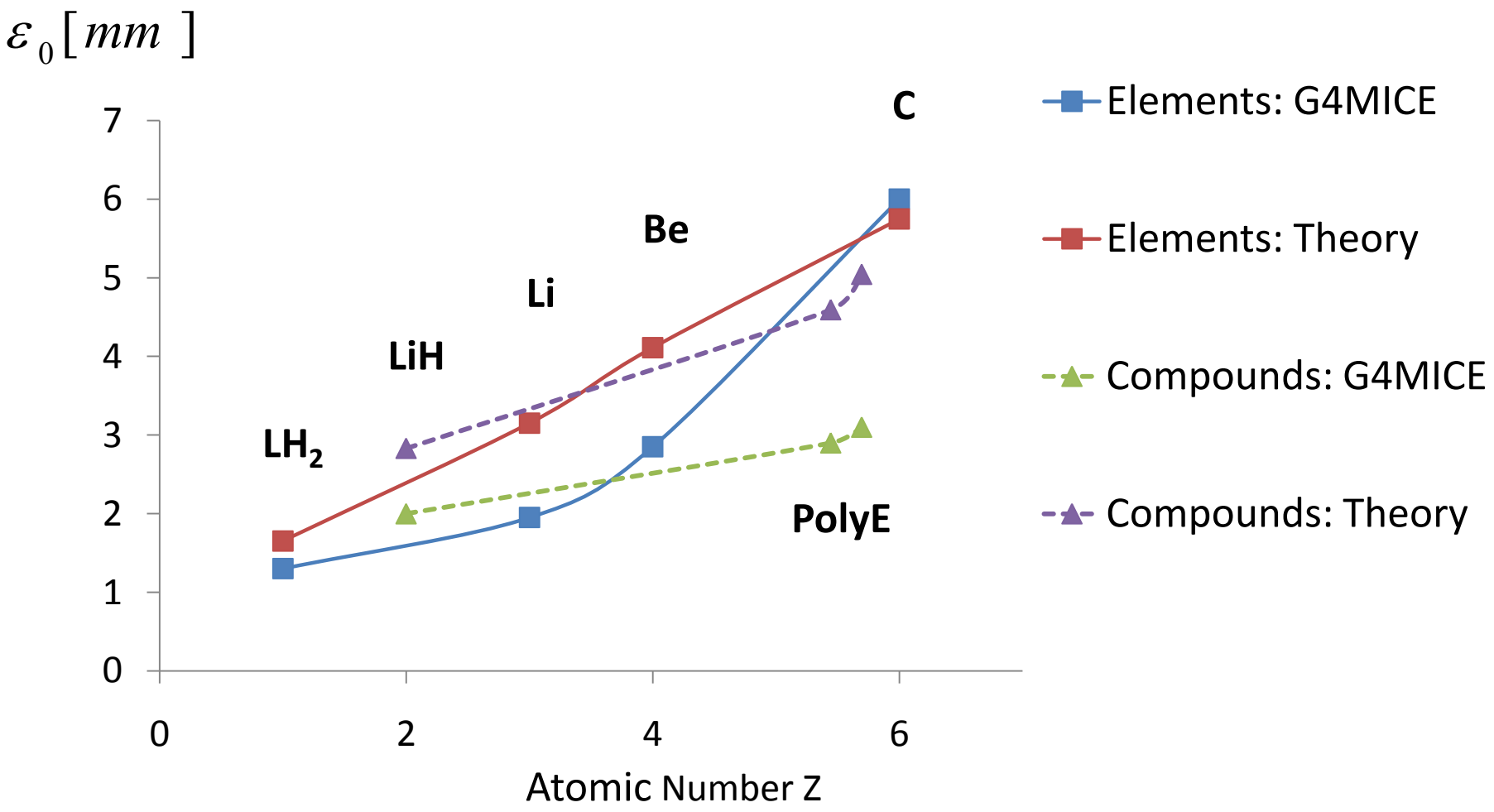
p_z = 207 MeV/c
N_μ = 10,000
σ_{Pz} = 1MeV/c
β_T = 41cm

$$\varepsilon_0 = \frac{\beta_T (14\,\mathrm{MeV}\ /\ \mathrm{c})^2}{2\beta m_\mu X_0} \left\langle \frac{dE}{dz} \right\rangle^{-1}$$

Absorber study



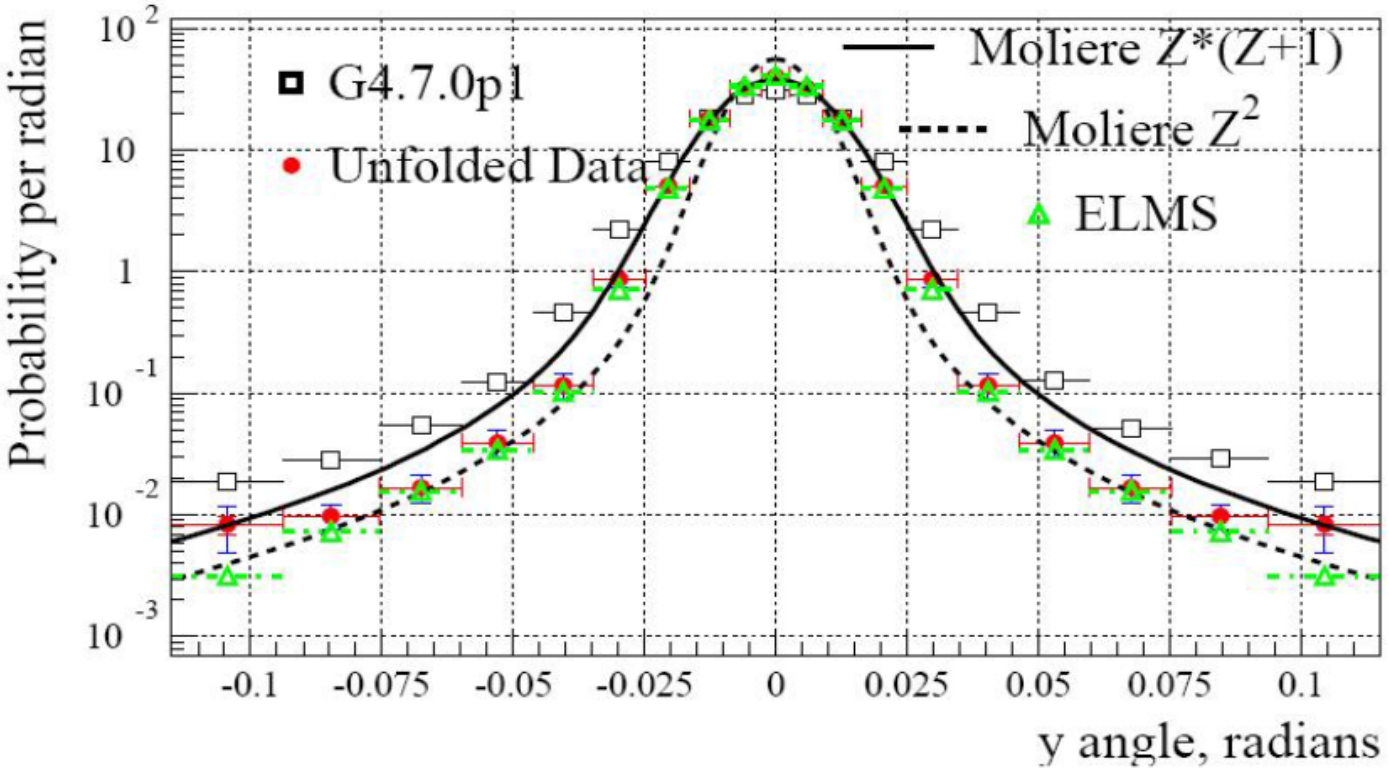
Equilibrium Emittance



MuScat Experiment

- Measured muon scattering.
- Compared with
  - GEANT 4.7.0 (10yrs old now)
  - **ELMS**

15.9cm LH2 Target



Summary

- Cooling formula/Moliere disagree with G4MICE
  - ε_0 1.5-2x less than predicted
  - Particularly bad with LH_2
- MuScat
  - Moliere & GEANT 4.7.0 overestimate scattering at low Z
  - ELMS code much better
- G4MICE uses GEANT 4.9.2 however...
  - Is this closer to MuScat?
  - **ELMS in MAUS**?

Scattering Angle (Li fraction)