Measuring Multiple Scattering in Step IV

Timothy Carlisle

Oxford

See MICE Note 374 for updated results

Intro.

- Step IV will **measure ε_0** in various materials.
- G4MICE finds ε_0 up to 30% less than predictions:

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

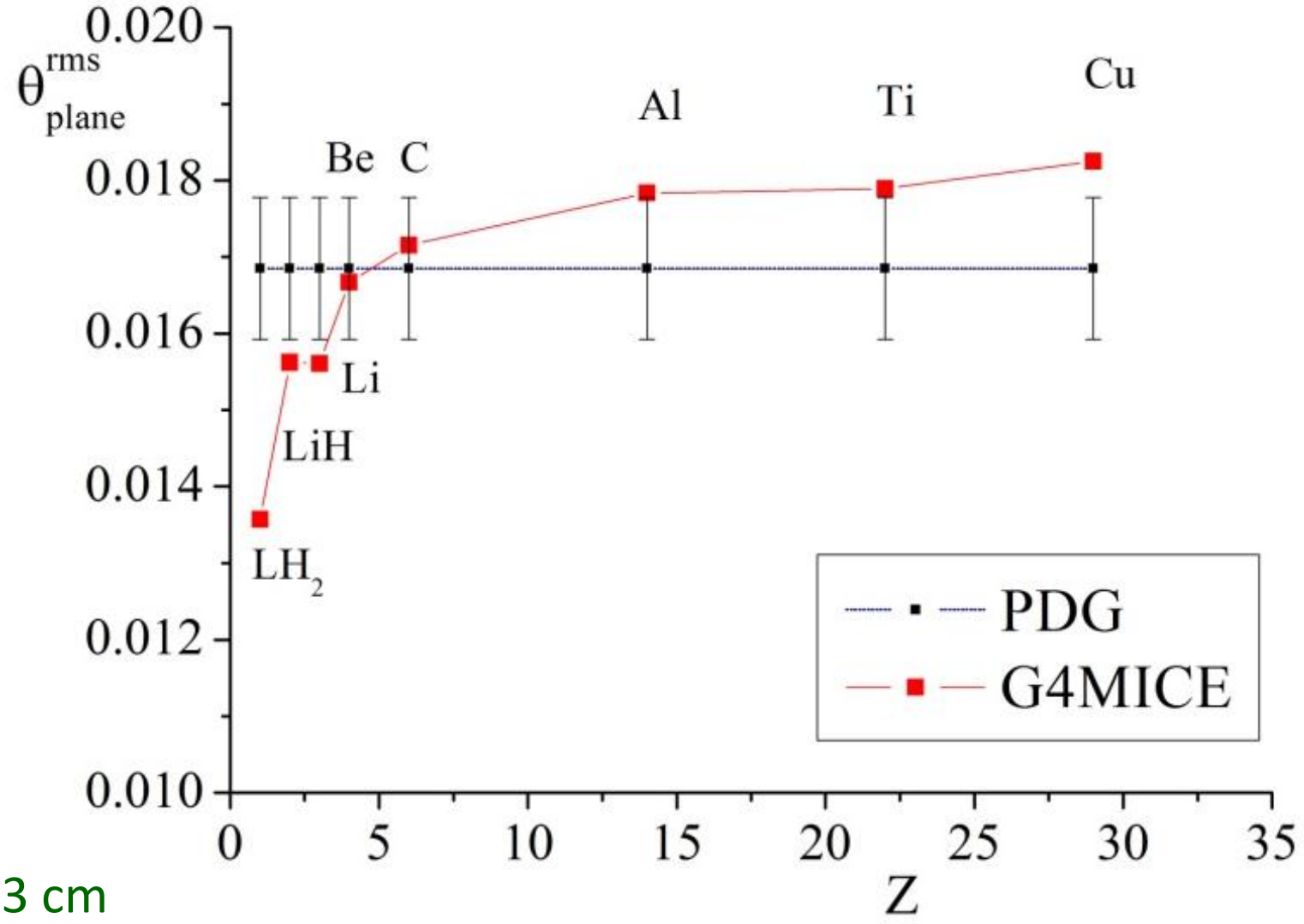
→Standard PDG Scattering angle expression:

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

$$\theta_{space}^{rms} = \sqrt{2}\ \theta_{plane}^{rms}$$

- Potential term actually **scales with Z.**
- Can we use the trackers to measure MS directly?

Scattering Angle comparison



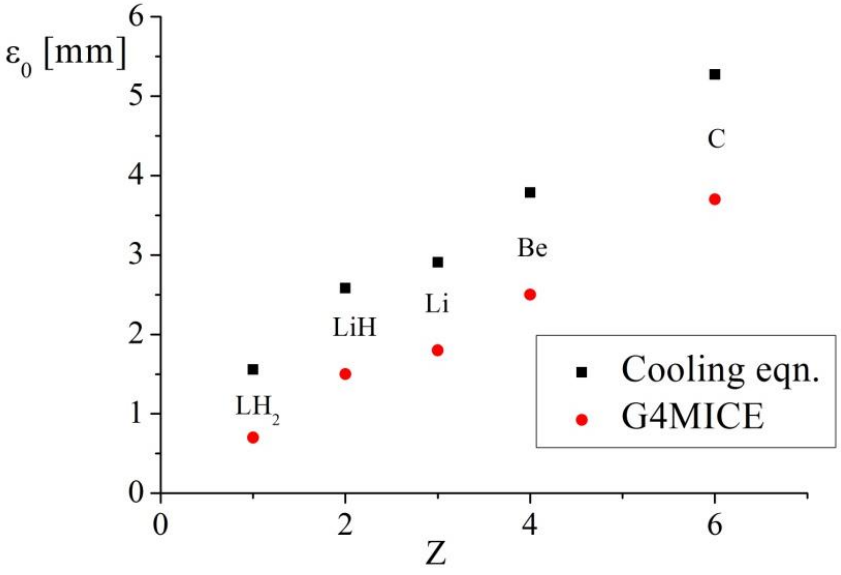
Note:

Δz_{LiH} = 6.3 cm

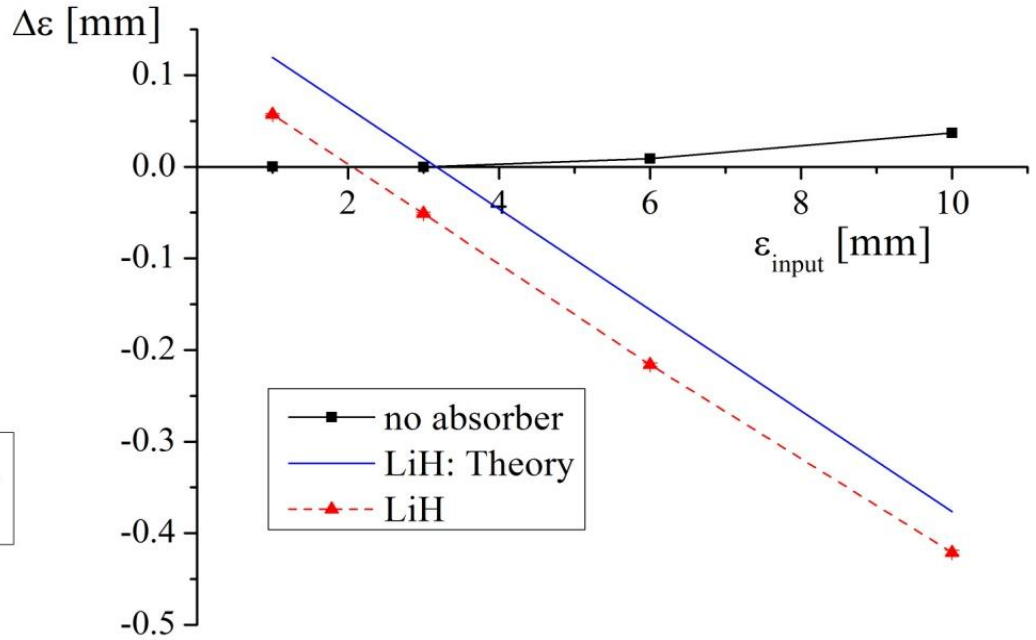
Δz_{LH2} = 57.6 cm

Related studies (1)

Cooling Eqn. vs G4MICE

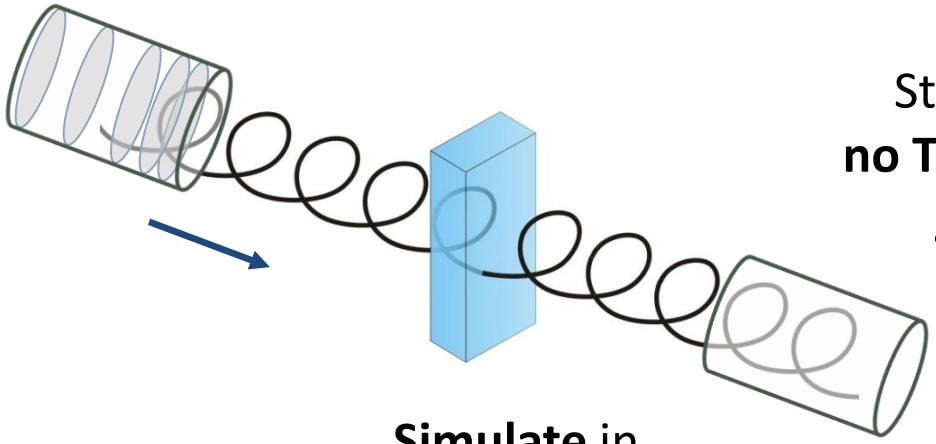


G4MICE: Step IV 63mm LiH



Method (1)

Start: Matched ε =2.5mm beam in upstream tracker



Step IV fields, **no Trackers in sim. geometry**

Simulate in G4MICE

- Four runs:
  - Empty channel & AFC
  - 35cm LH_2 & 63mm LiH
- Trk. Rec. still in the pipeline.
- Apply a **smear** instead, Gaussian, given:

- Trk. Rec. to give 6D particle vectors at Trk. Ref Planes:

$$z = -4.65 \text{ m} \;\&\; -0.85 \text{ m}$$

MICE Note #90

$\sigma_x = 0.54\text{mm}$

$\sigma_y = 0.44\text{mm}$

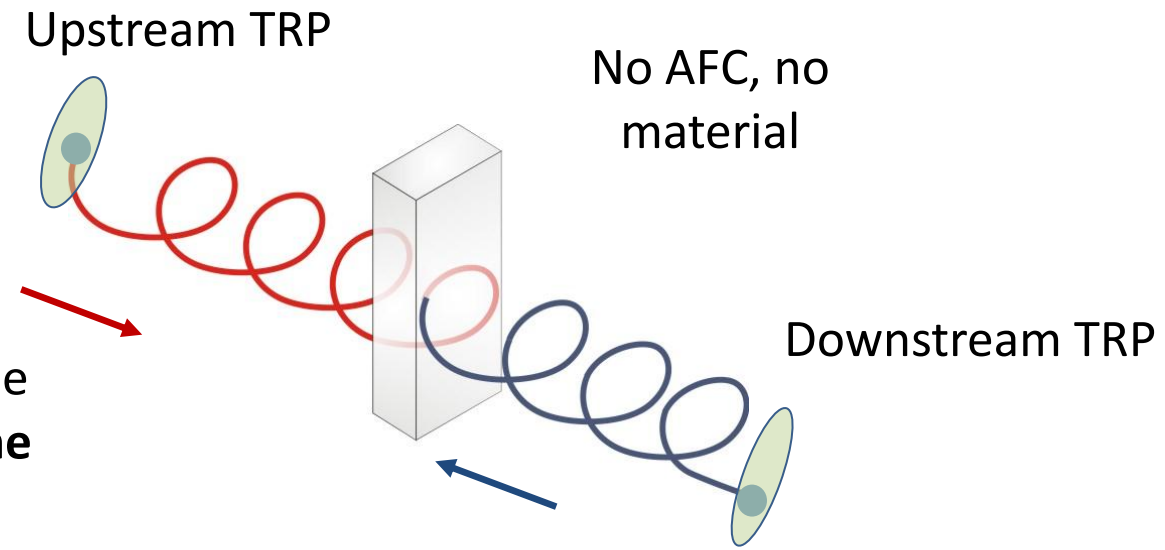
$\sigma_{Px} = 2.05\text{MeV/c}$

$\sigma_{Py} = 1.52\text{MeV/c}$

$\sigma_{Pz} = 4.58\text{MeV/c}$

Method (2)

- Re-simulate in an <u>empty geometry</u> (just fields)
- Track **downstream beam** up to the absorber
  - Flip momenta
  - Flip particle sign also
  - No energy losses
- Track **upstream beam** down through the absorber:

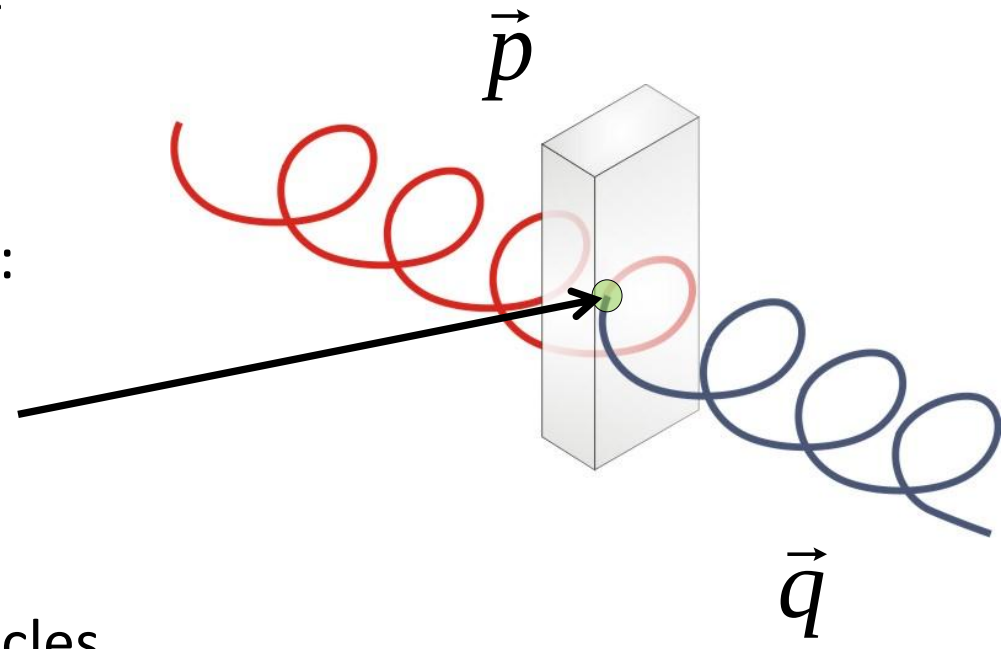


Method (3)

i) Take vectors at DS edge of Absorber position

ii) Calc. angle between them:

$$\cos\theta_{rms}^{space} = \frac{\vec{p}.\vec{q}}{|p||q|}$$



iii) Plot histogram for all particles.

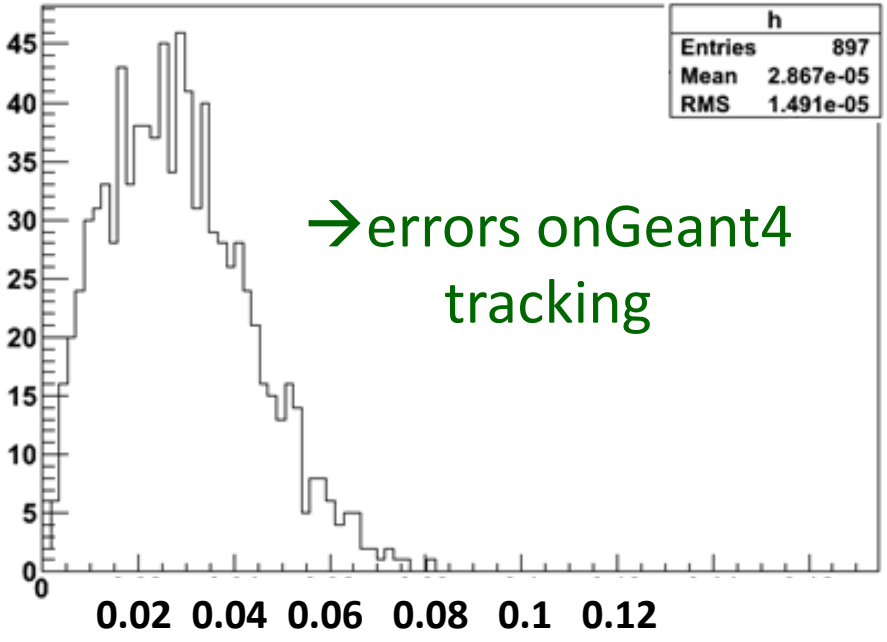
iv) Note: $\text{ROOT rms} = \sqrt{\text{variance}}$

Where: $\text{variance} = \langle\theta^2\rangle - \langle\theta\rangle^2$

$\Rightarrow \langle\theta^2\rangle = (\text{ROOT rms})^2 + \langle\theta\rangle^2$

No AFC (empty geometry)

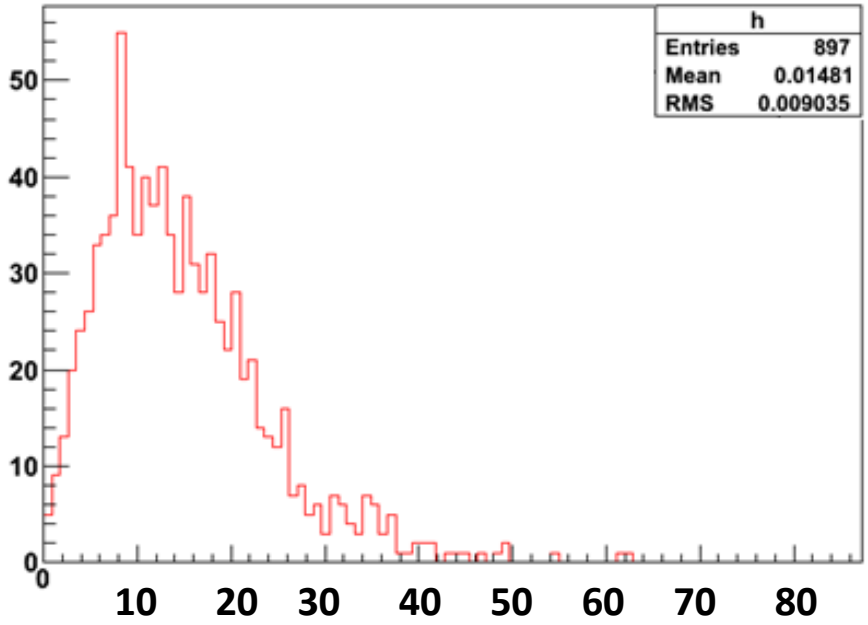
No Smear



→errors onGeant4 tracking

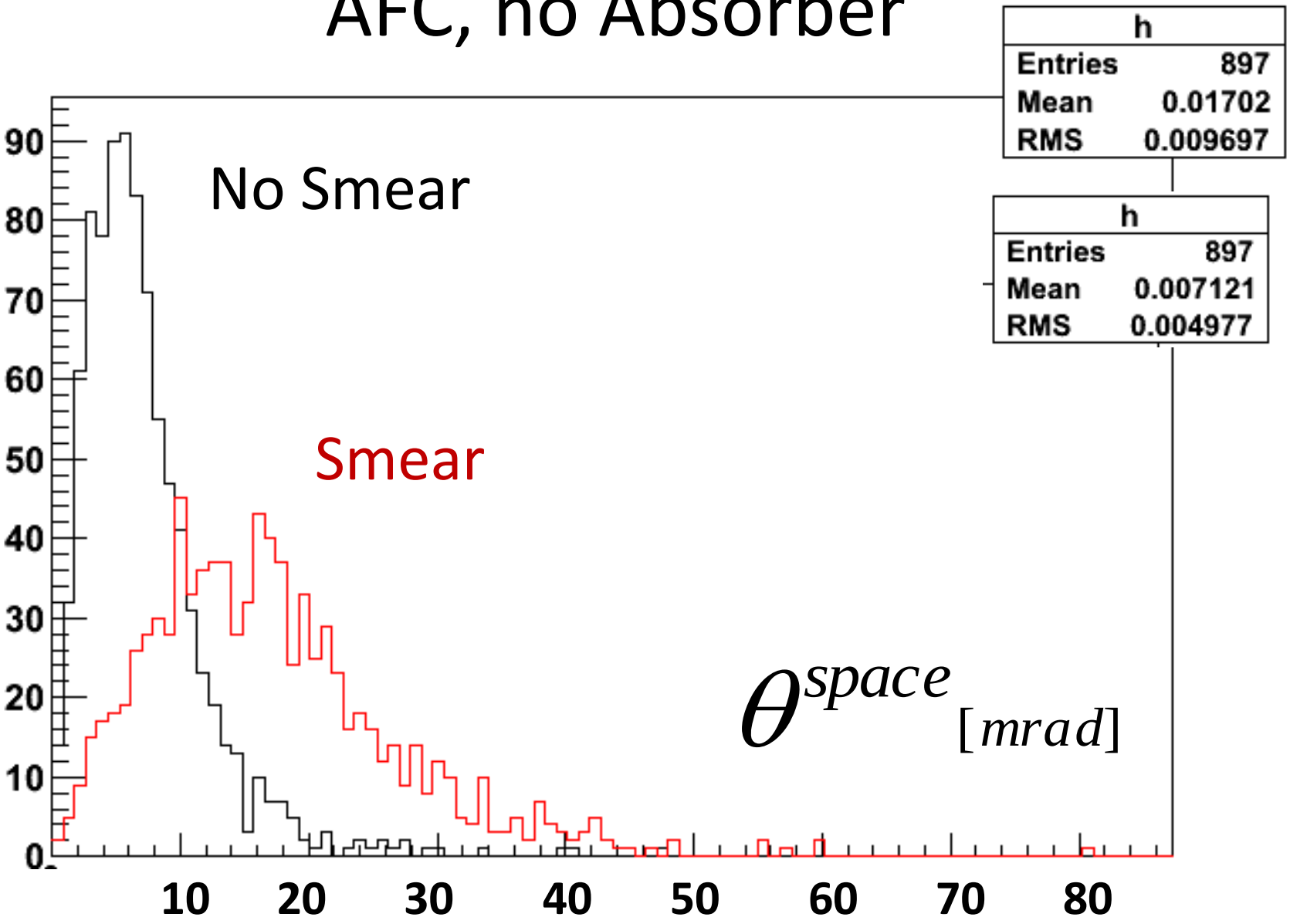
$\theta^{space}_{[mrad]}$

Smear

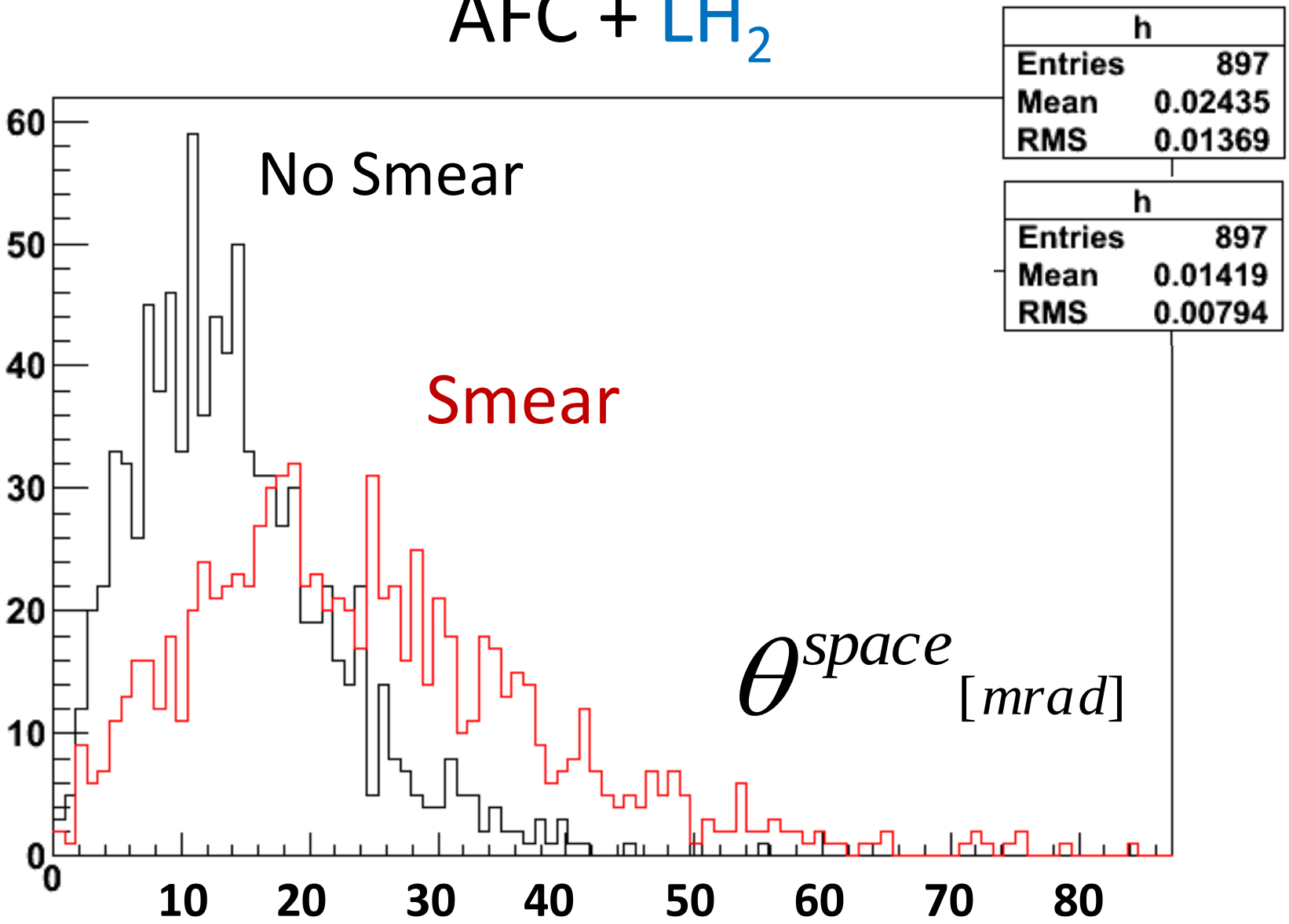


$\theta^{space}_{[mrad]}$

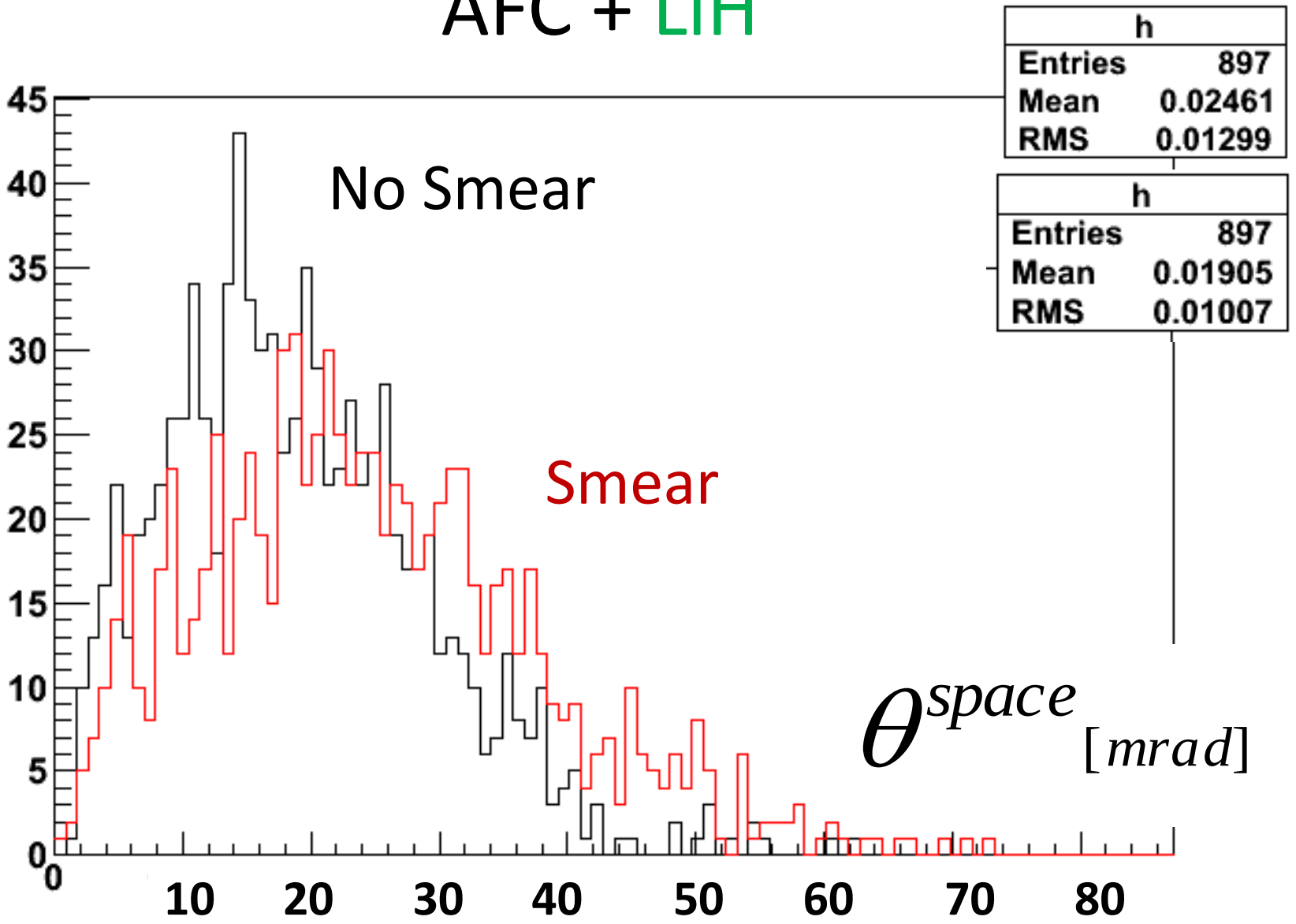
AFC, no Absorber



AFC + LH_2

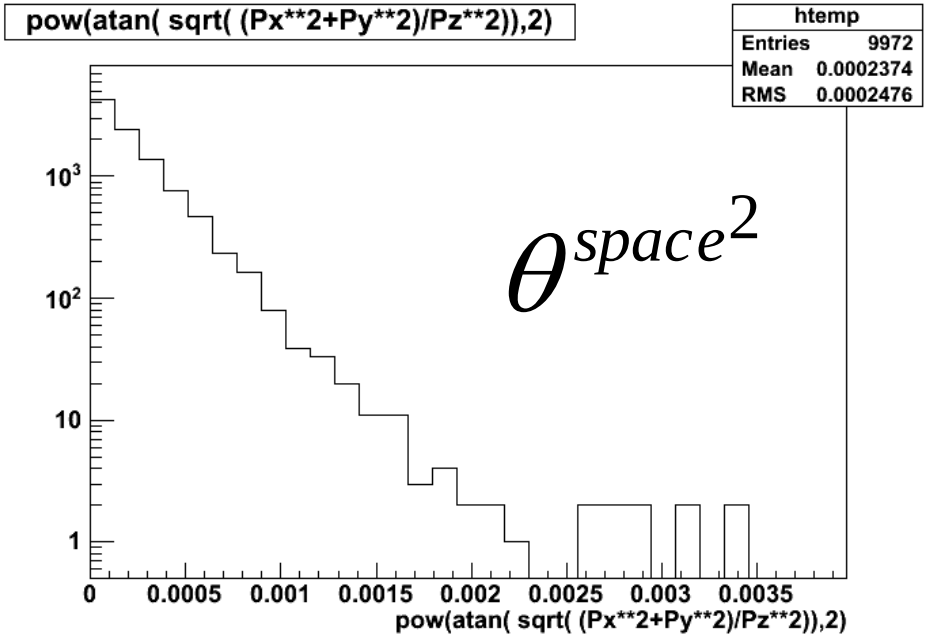

h
Entries 897
Mean 0.02435
RMS 0.01369
h
Entries 897
Mean 0.01419
RMS 0.00794
No Smear
Smear
θ^{space} [mrad]
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80

AFC + LiH

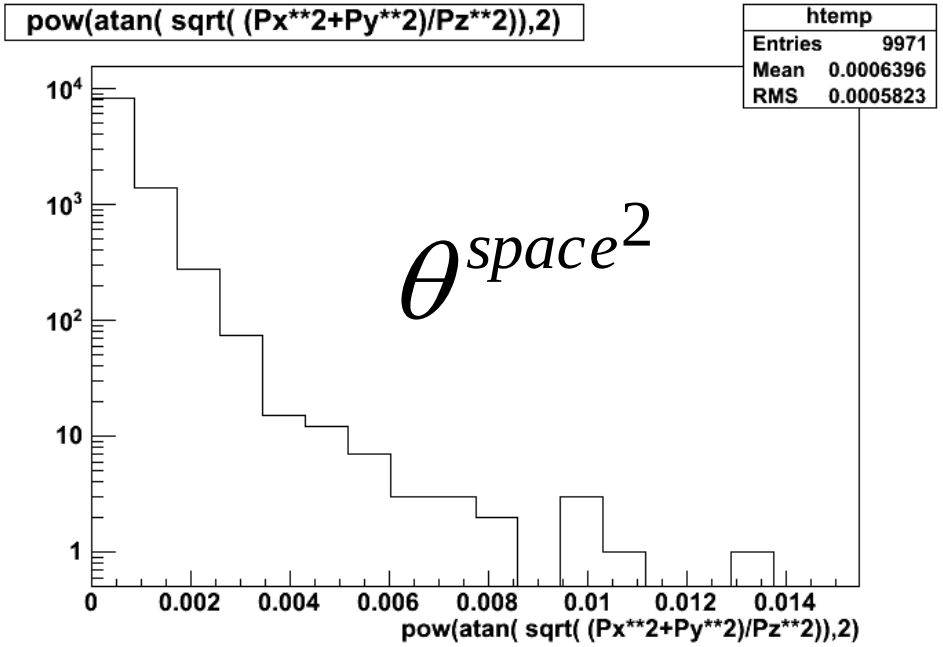

h
Entries 897
Mean 0.02461
RMS 0.01299
h
Entries 897
Mean 0.01905
RMS 0.01007
No Smear
Smear
θ^{space} [mrad]
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
80

Paraxial beams in G4MICE

35 cm LH_2



63 mm LiH



Results

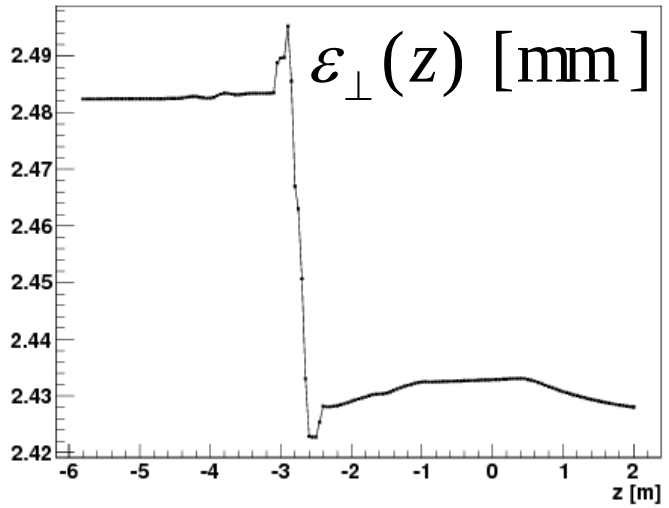
	θ_{rms}^{space}			
	No Smear ($\varepsilon_\perp$ = 2.5 mm)	**Smear**	**PDG**	**Pencil beam**
No AFC	3.23e-5	1.73e-2		($\varepsilon_\perp \equiv 0$ mm)
AFC (windows)	8.69e-3	1.96e-2		
LH_2	1.63e-2	2.79e-2	1.87e-2	8.9e-3
LiH	2.15e-2	2.78e-2	2.46e-2	2.03e-2

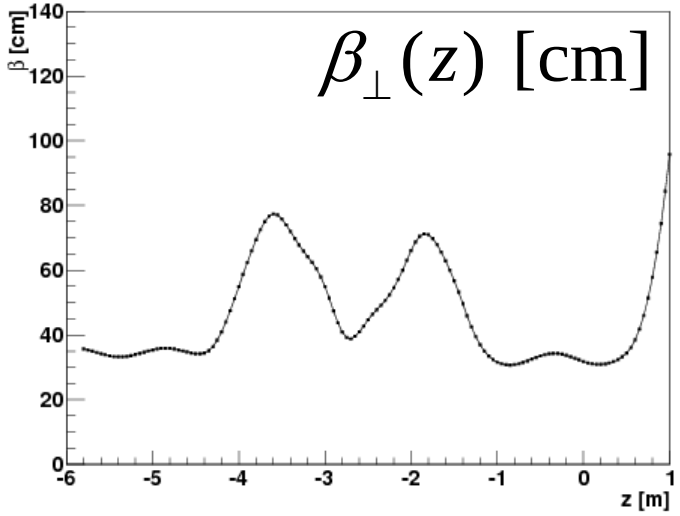
Summary

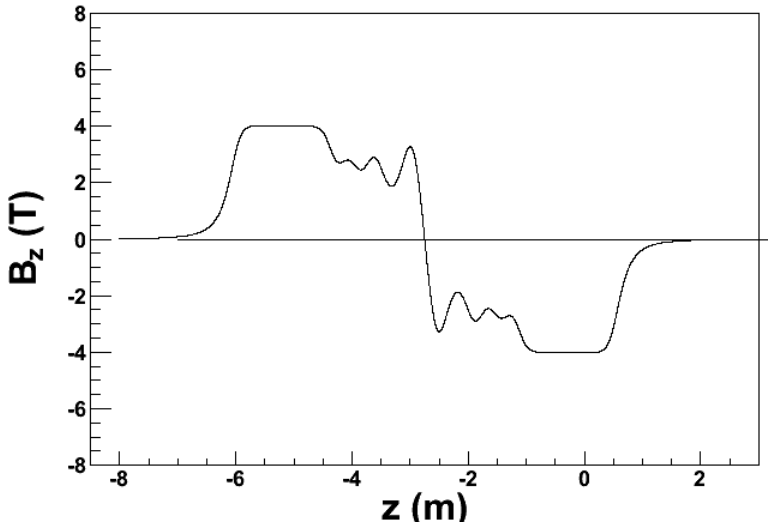
- PDG ~ 2x more scattering than G4MICE.
- Smearing may require further thought re: correlations
- LH_2 & LiH indistinguishable after smear.
- LiH measurement < PDG angle.
- **See MICE Note 374 for updated results**

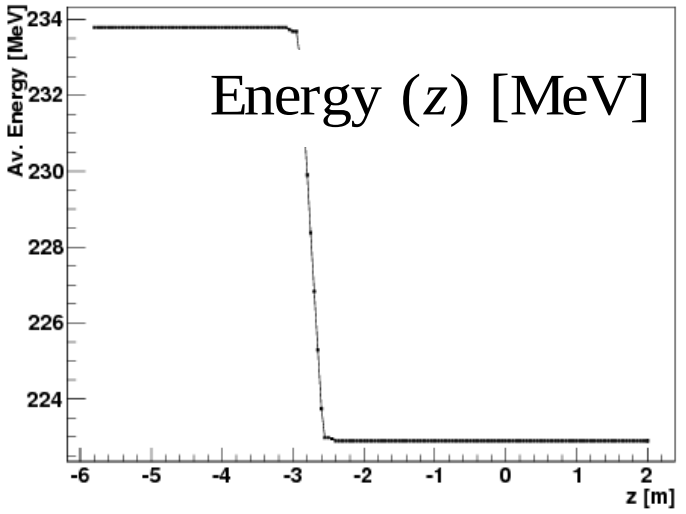
EXTRAS

G4MICE output - 35 cm LH_2





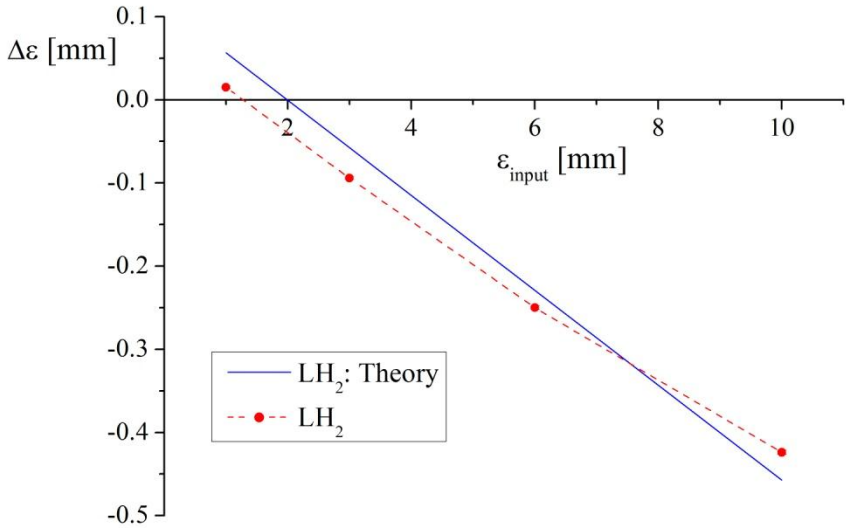




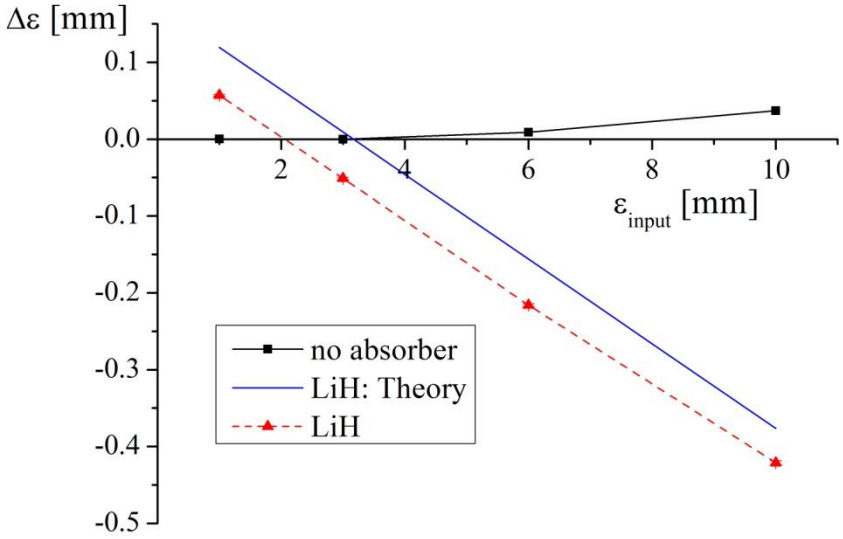
Related studies (2)

From CM28

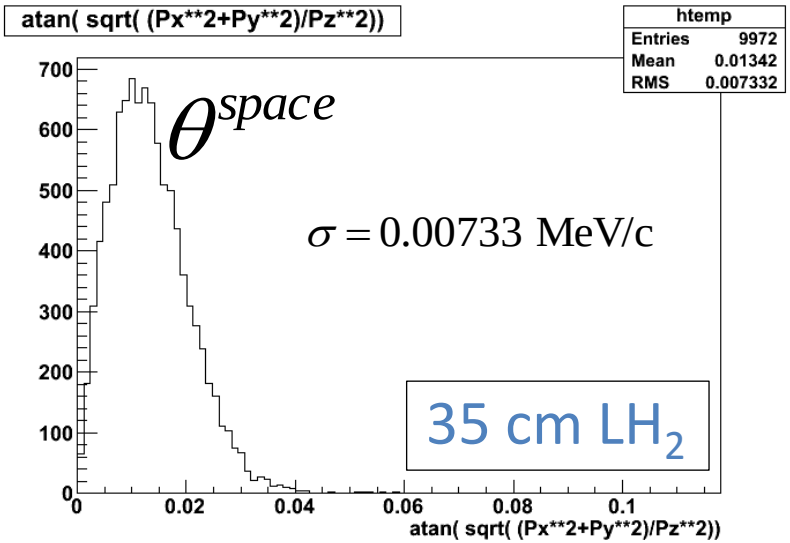
Step IV: LH_2

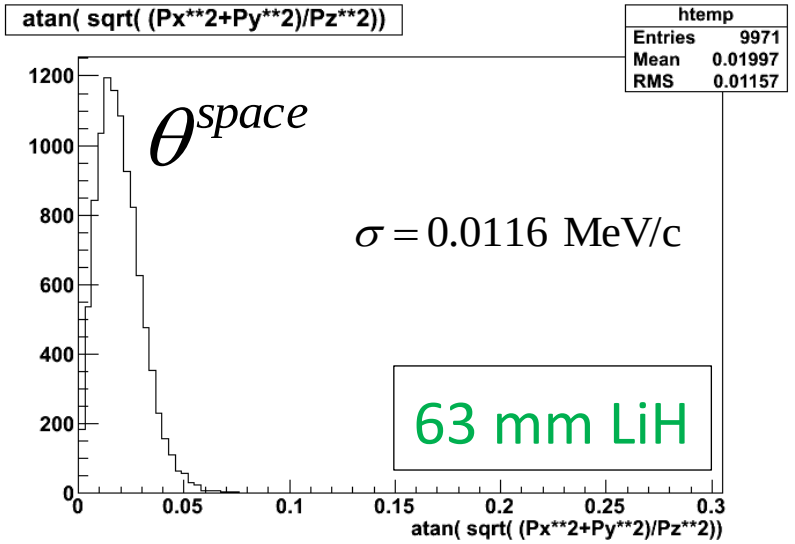


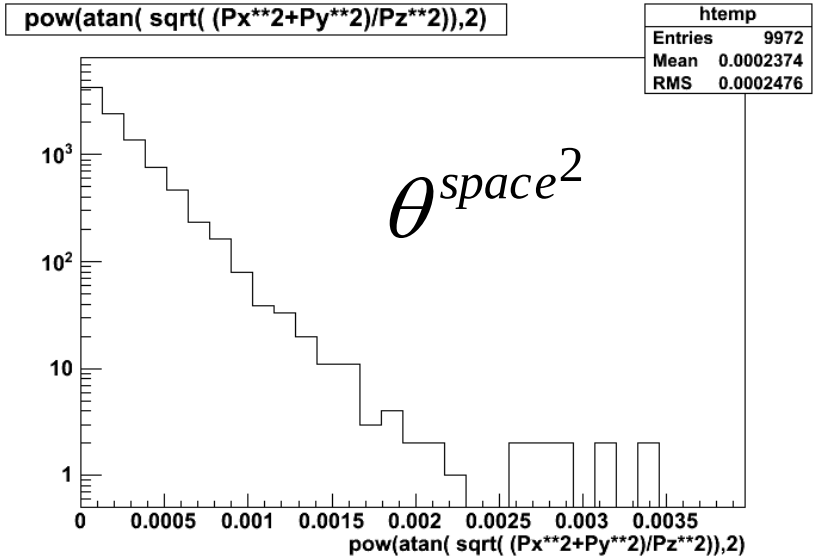
Step IV: LiH

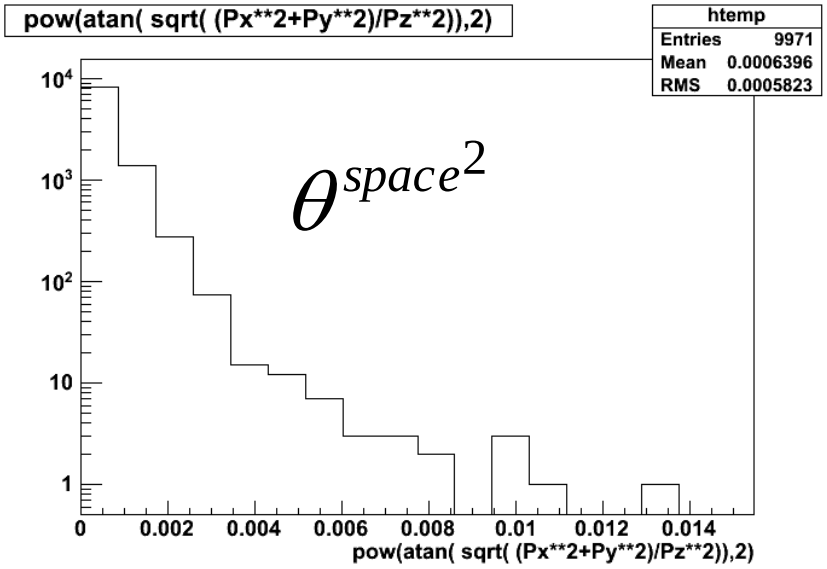


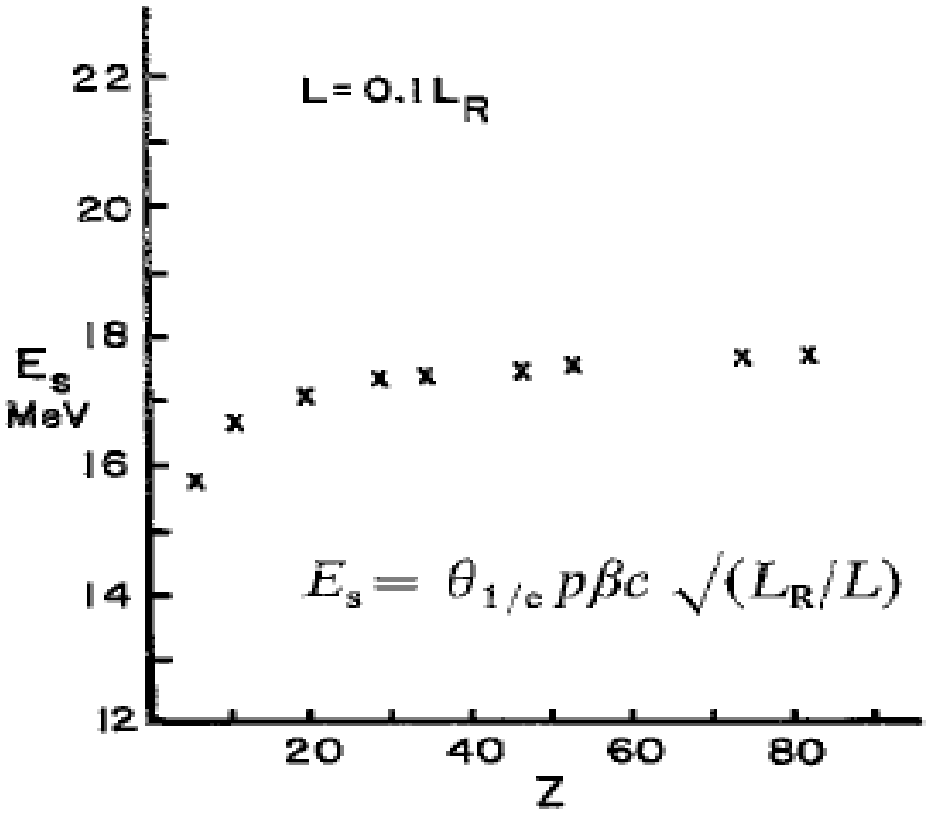
paraxial beams in G4MICE





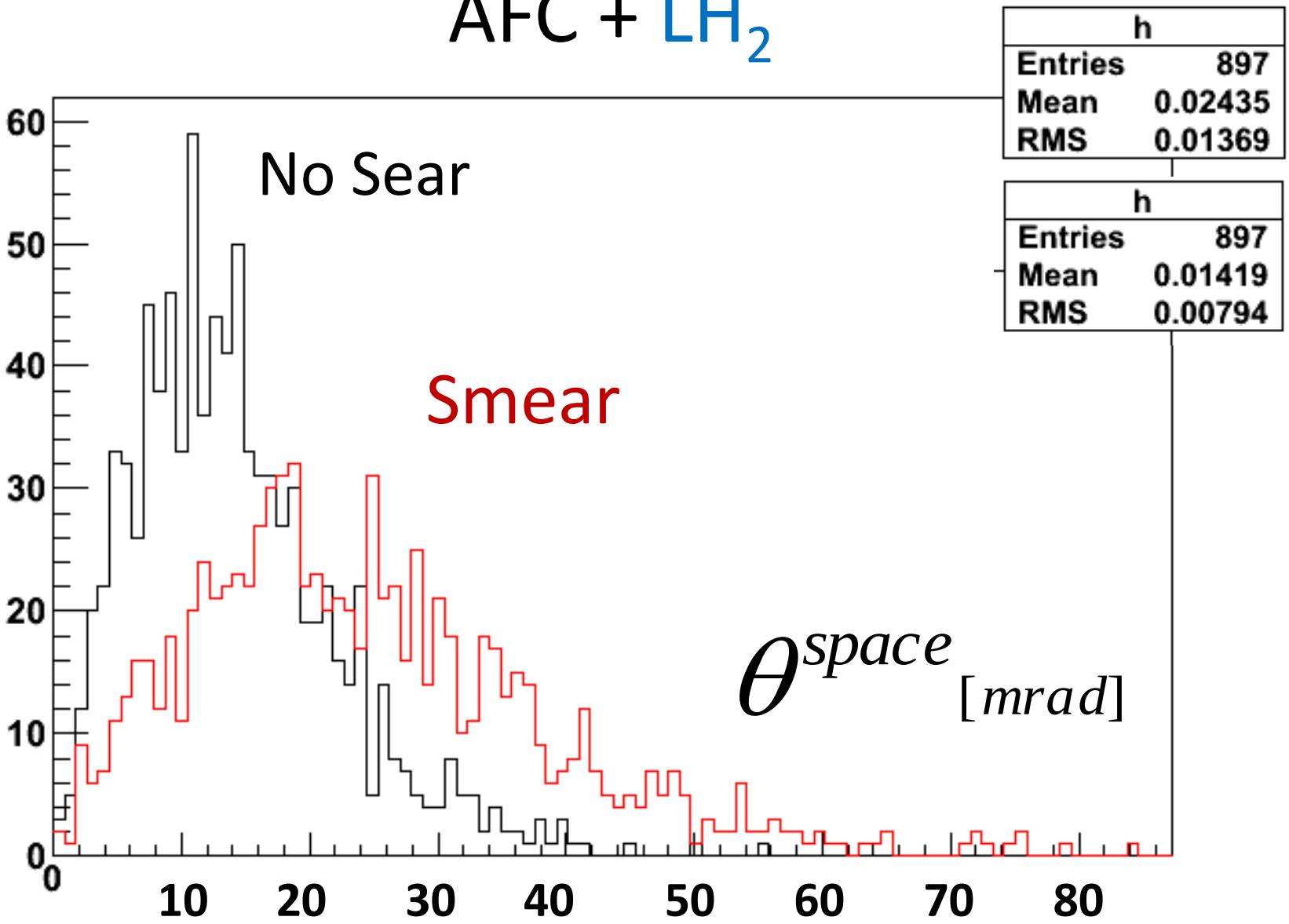


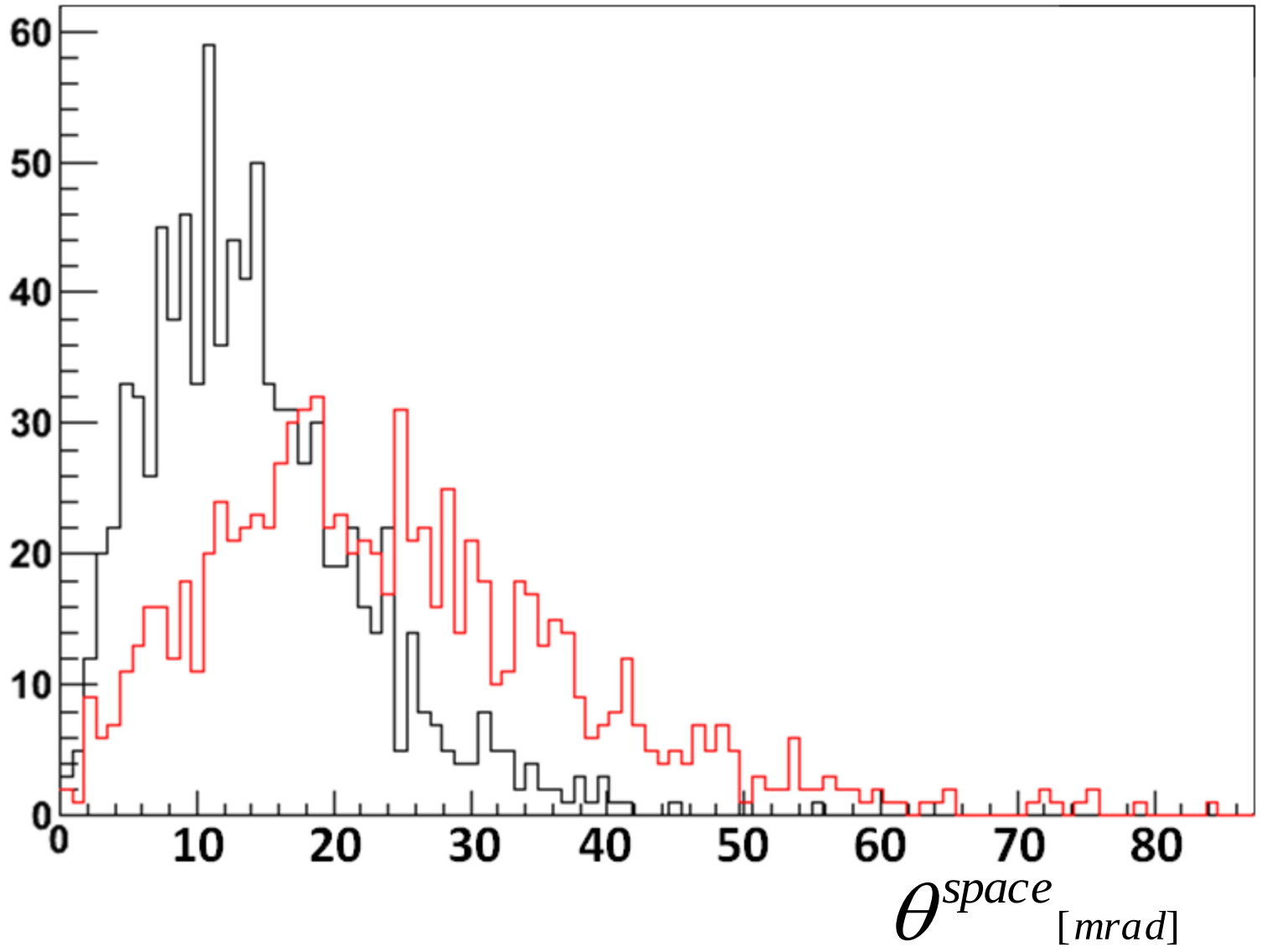


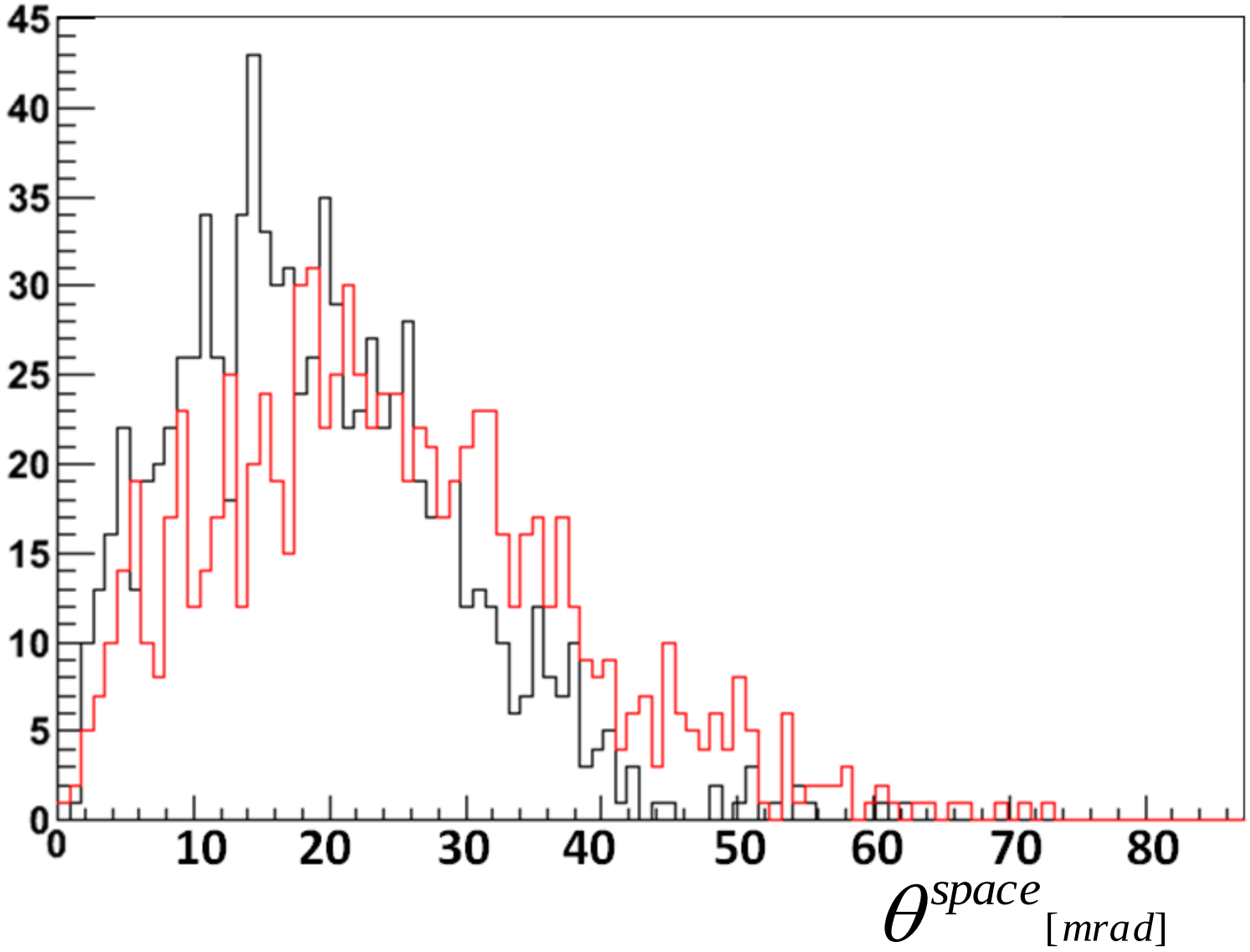


V.L. Highland, Nucl. Instrum. Methods 129, 497 (1975)

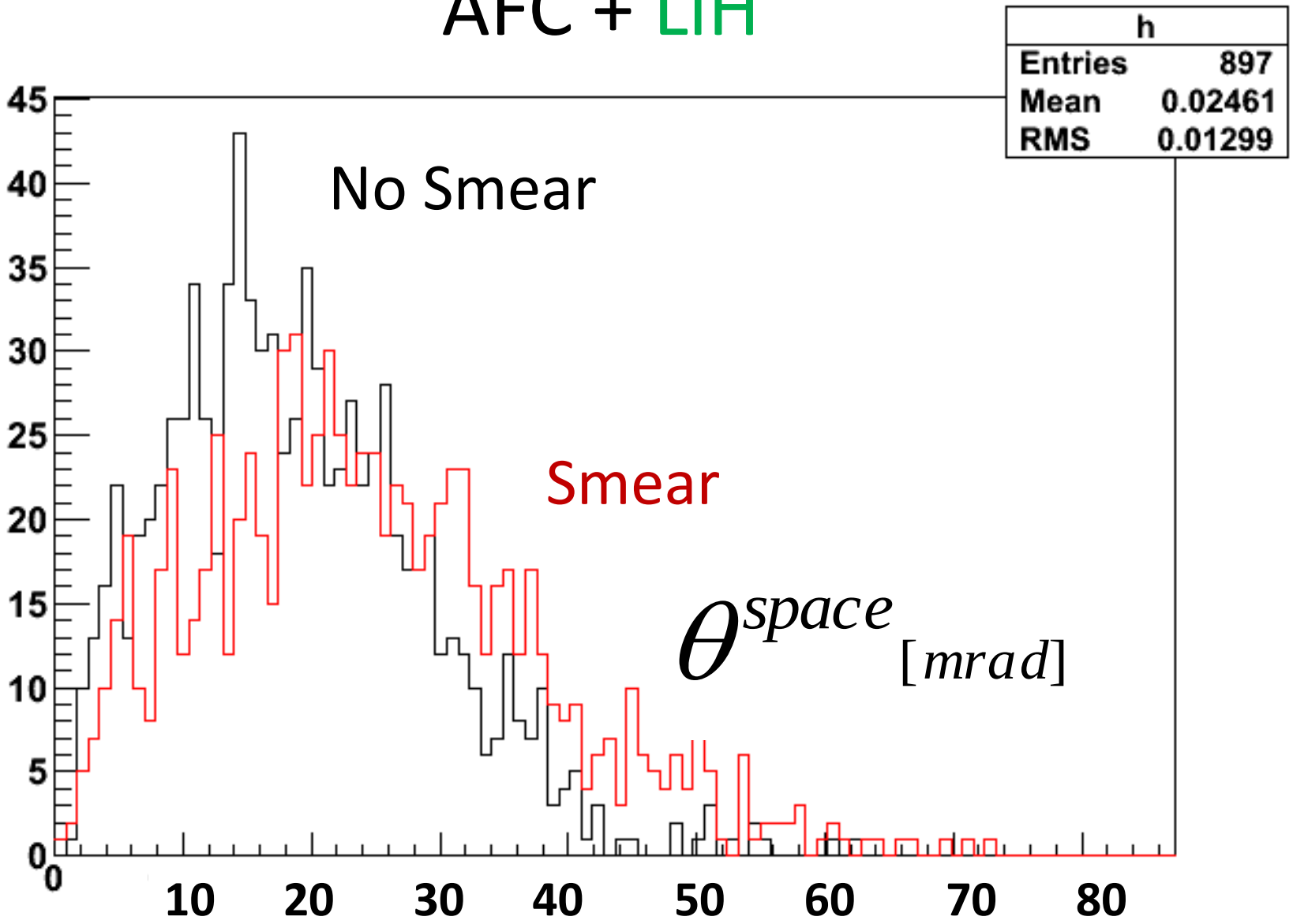
AFC + LH_2


h
Entries 897
Mean 0.02435
RMS 0.01369
h
Entries 897
Mean 0.01419
RMS 0.00794
No Sear
Smear
θ^{space} [mrad]
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80


60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
θ^{space} [mrad]


45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
θ^{space} [mrad]

AFC + LiH


h
Entries 897
Mean 0.02461
RMS 0.01299
No Smear
Smear
θ^{space} [mrad]
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
80