Changes in MSC model (G4UrbanMscModel-G4UrbanMscModel2)

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Angular distribution in the model is described by eqs.

$$g(u) = q[pg_1(u) + (1 - p)g_2(u)] + (1 - q)g_3(u) \qquad (1)$$

$$g_1(u) = C_1 \ e^{-a(1-u)} \qquad -1 \le u_0 \le u \le 1 \qquad (2)$$

$$g_2(u) = C_2 \ \frac{1}{(b - u)^d} \qquad -1 \le u \le u_0 \le 1 \qquad (3)$$

$$g_3(u) = C_3 \qquad -1 \le u \le 1 \qquad (4)$$

where $u = cos\theta$, $a > 0$, $b > 0$, $d > 0$ and u_0 are model parameters, and the C_i are normalization constants. It is worth noting that for small scattering angles, θ, $g_1(u)$ is nearly Gaussian $(exp(-\theta^2/2\theta_0^2))$ if $\theta_0^2 \approx 1/a$, while $g_2(u)$ has a Rutherford-like tail for large θ, if $b \approx 1$ and d is not far from 2 .

6 model parameters : a,b,d,u_0,p and q.

constraints : $g(u)$ and its 1st derivative should be continuous at $u = u_0$

mean value of $u = cos\theta$ should be same as it is from theory

$\longrightarrow$ 3 free parameters

choice : a,d and $\xi = a(1 - u_0)$

$\xi = 3$ in both model and model2 a and d differ.

It is worth to note that using the parametrization below

2nd moment of u is approximately same as theory

q is very near to 1 (practically no constant term in angle distribution) In the next slides parametrization of model2 is given when it differs from model.

The parameter a was chosen according to a modified Highland-Lynch-Dahl formula for the width of the angular distribution

$$a = \frac{0.5}{1 - cos(\theta_0)} \qquad (5)$$

where θ_0 is

$$\theta_0 = \frac{13.6 MeV}{\beta cp} z_{ch} \sqrt{\frac{t}{X_0}} \left[a_1 + a_2 \ln \left(\frac{t}{X_0} \right) \right] \qquad (6)$$

where p, βc and z_{ch} are the momentum, velocity and charge number of the incident particle, t/X_0 is the true path length in radiation length units. Here the parameters a_1 and a_2 are function of the target atomic number (Z) only. (In the Highland formula $a_1 = 1$, $a_2 = 0.038$)

TUNING : try to choose a_1 , a_2 in such a way that MC results reproduce the width of the measured angular distributions.

this tuning can be done independently from the d tuning for a thin layer and using 1 step to cross the layer Using the classical measurements of Hansen et al. (15.7 MeV e- in Be,Au) and of Latyshev at al (2.25 MeV e- in Al,Fe,Cu,Mo,Ag,Ta,Au and Pb)

in model2 we got

$$a_1 = (1. - \frac{0.08778}{Z}) * (0.87 + 0.03 * lnZ) \qquad (7)$$

$$a_2 = (0.04078 + 0.00017315 * Z) * (0.87 + 0.03 * lnZ) \qquad (8)$$

tuning of parameter d:

for thin layer, 1 step one should reproduce the measured tail

BUT: there are very few measurement of the tail , in the classical electron scattering experiments only the 15.7 MeV e- Au gives the tail (with rather big error)

$\longrightarrow$ try to find a parametrization for d from the requirement of step independence (i.e. the angle distribution should not depend on the number of steps).

The exact step independence probably can not be reached in this simple model, but the approximate step independence is a realistic goal. The d tuning is a quite difficult business : if the particle traverses the target in several steps , BOTH the central part and tail of the angle distribution depend on a AND d.

Parametrization of parameter d in model2 :

$$d = d_1 + d_2 \ln \left(\frac{t}{X_0} \right) \tag{9}$$

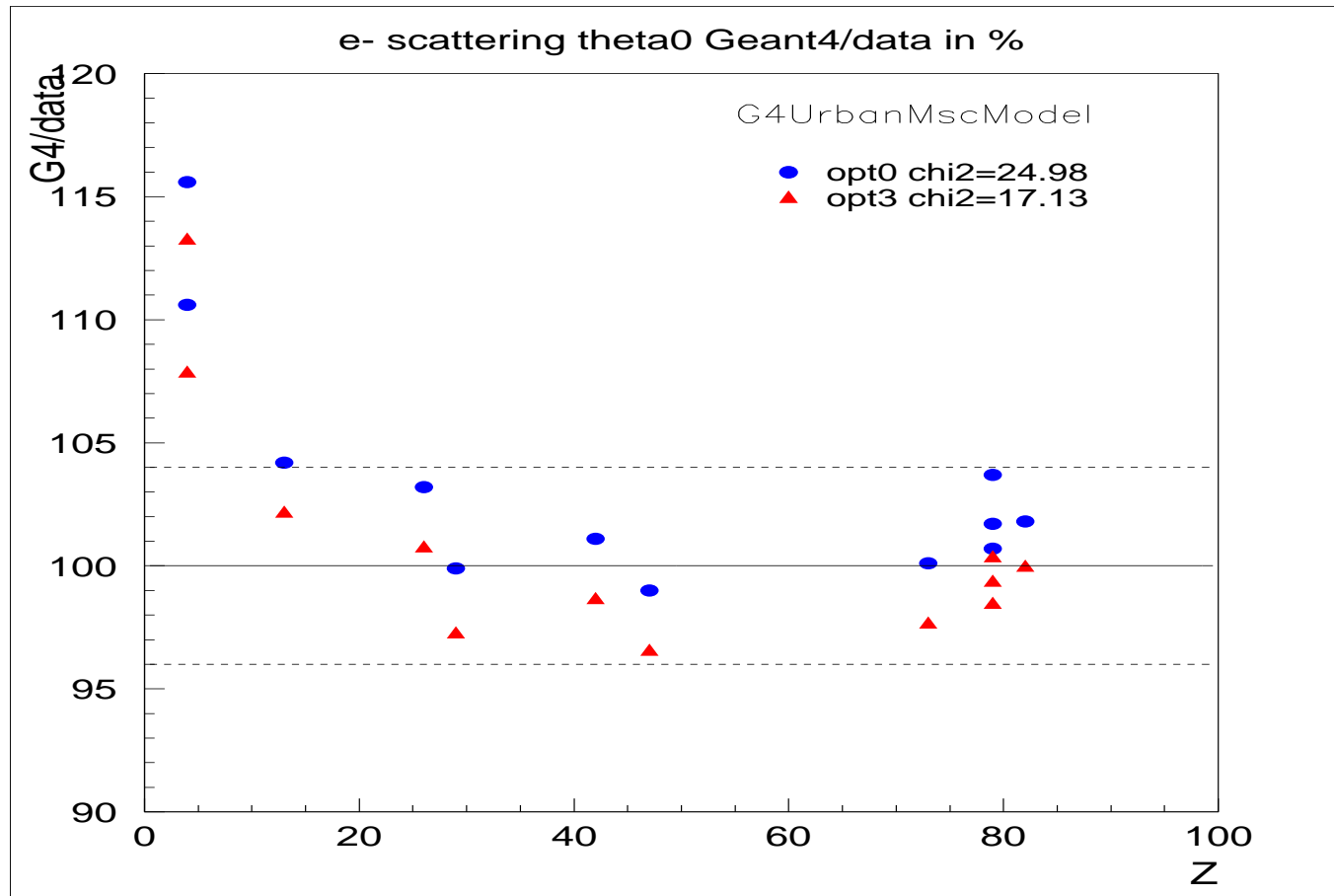$$d_1 = 2.943 - 0.197 * \ln(Z + 1) \tag{10}$$

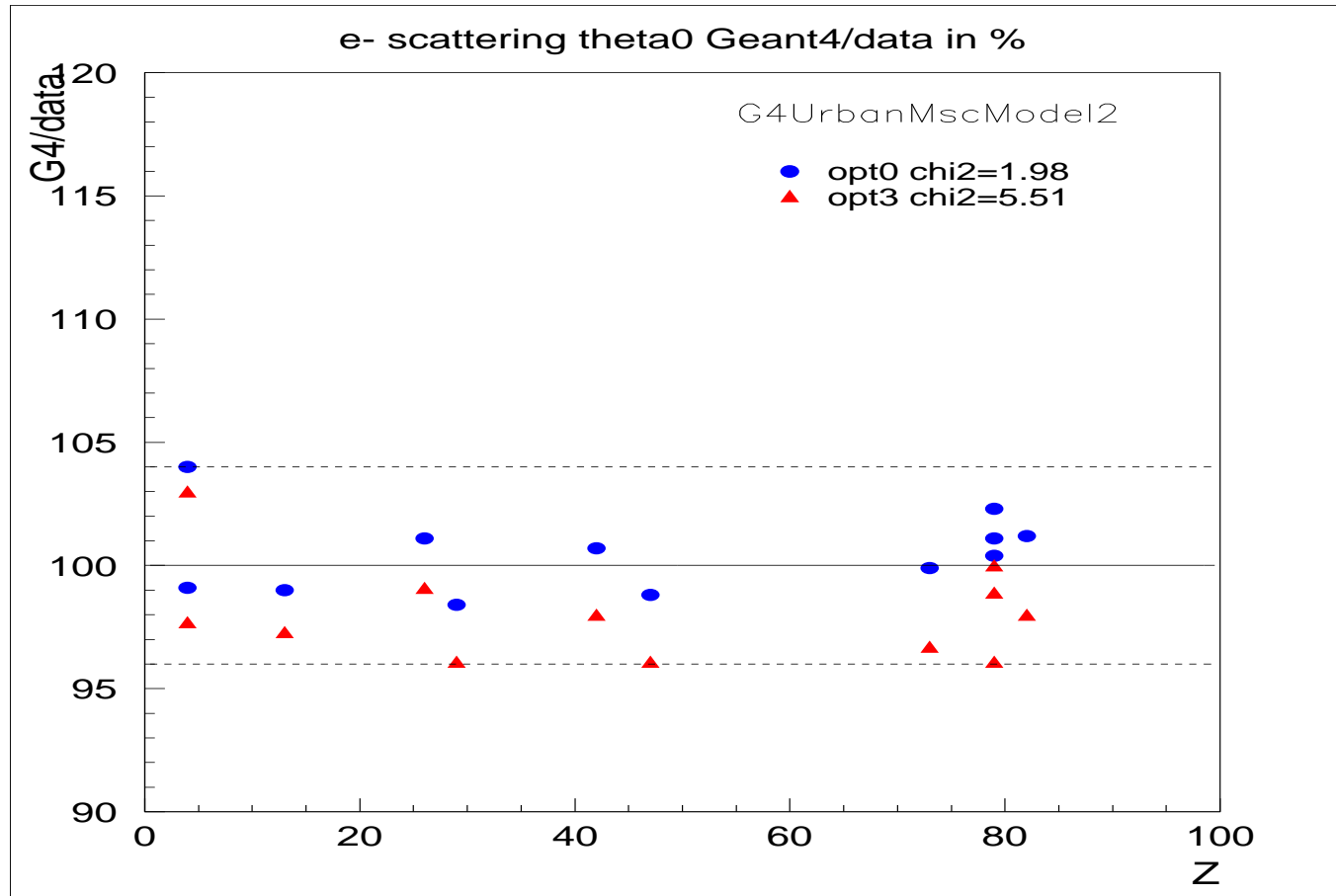$$d_2 = 0.0987 - 0.0143 * \ln(Z + 1) \tag{11}$$

The step length dependence of d is similar to that of parameter a. It can be seen from expressions of d_1, d_2 that the tail of the angle distribution shorter for low Z and longer for high Z materials. The next slides show some model - model2 - data comparisons. The quantity CHI2 is defined as
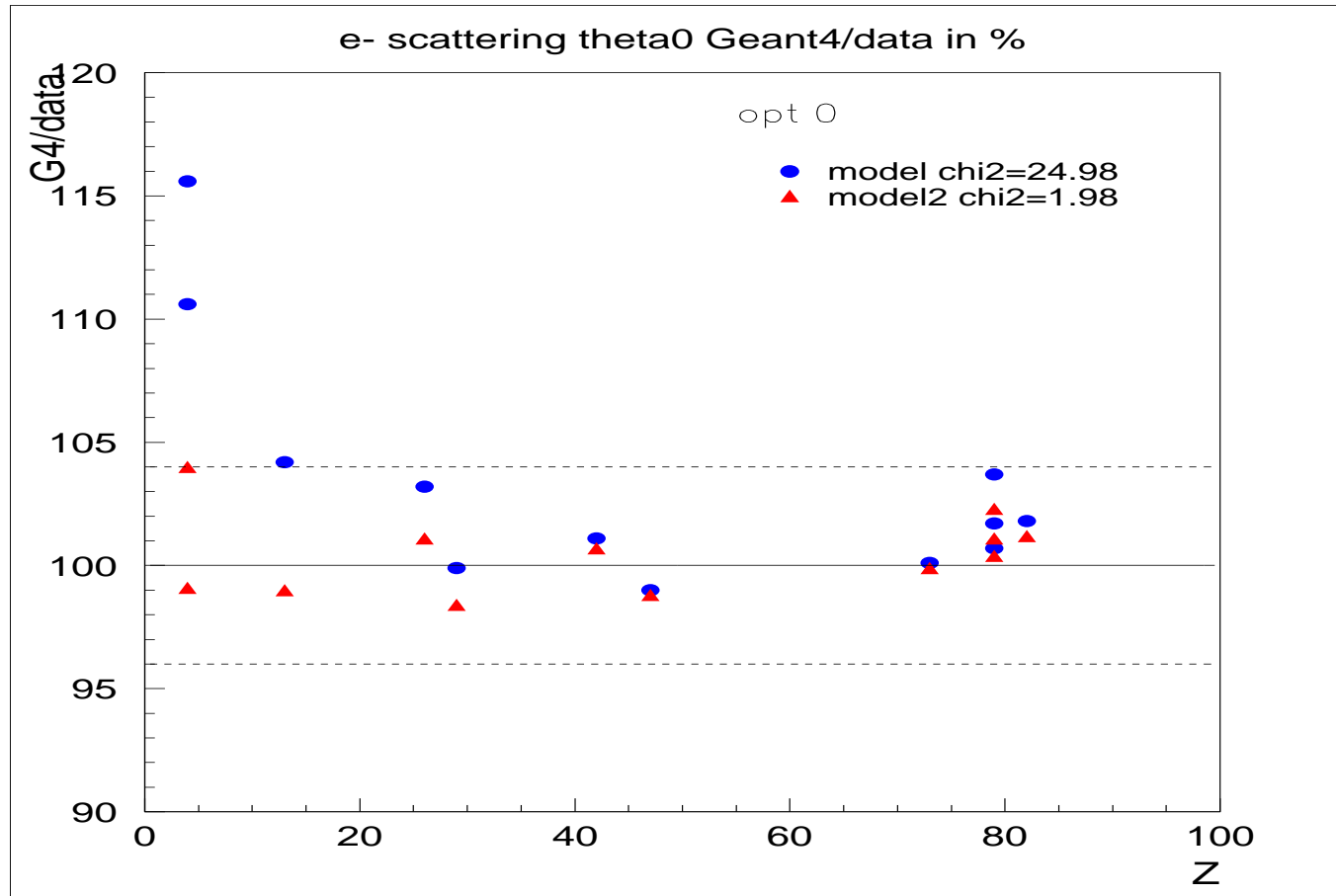
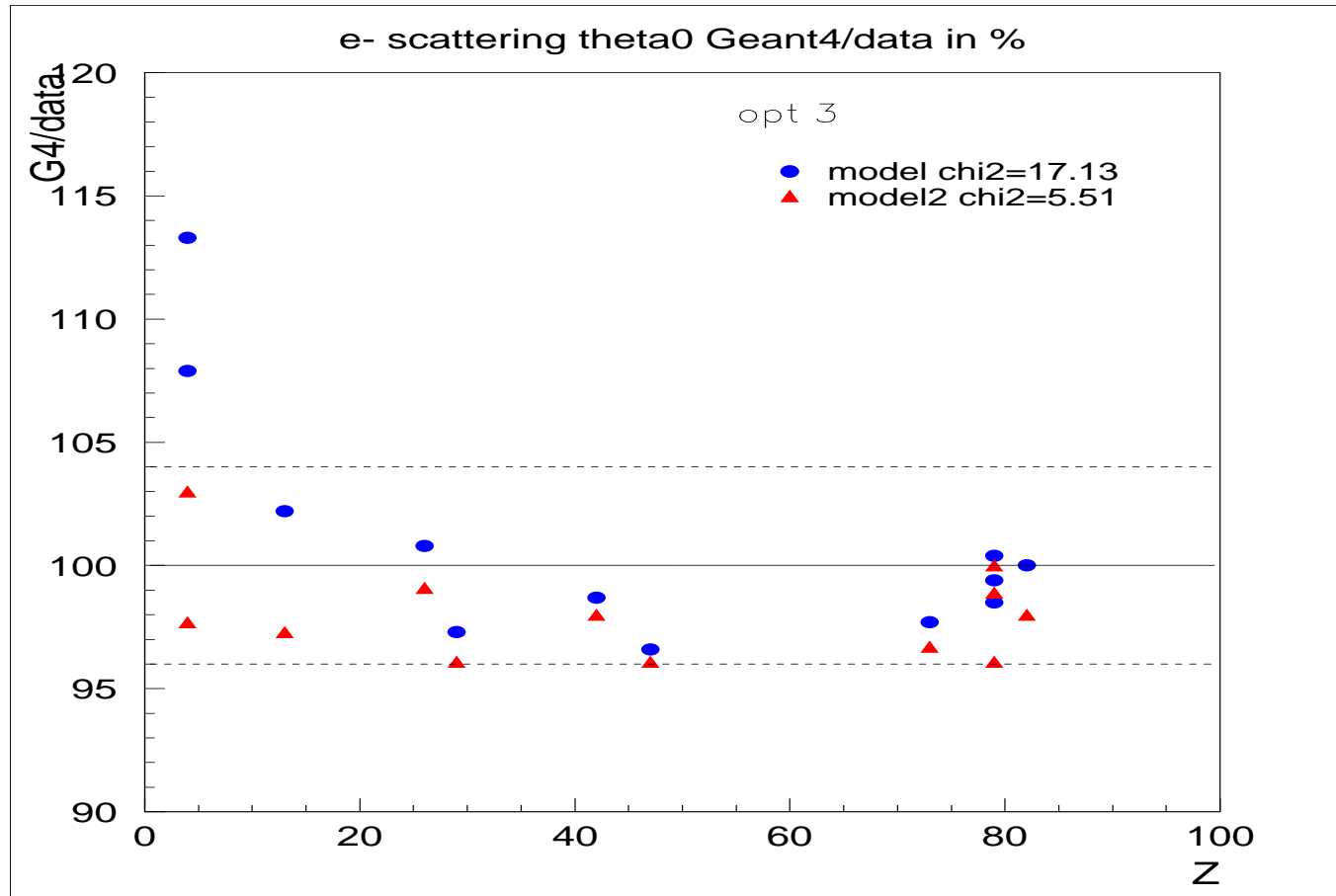$$CHI2 = \sum_i \frac{(G4_i - data_i)^2}{\sigma_i^2} \tag{12}$$

where σ_i are the exp. errors.
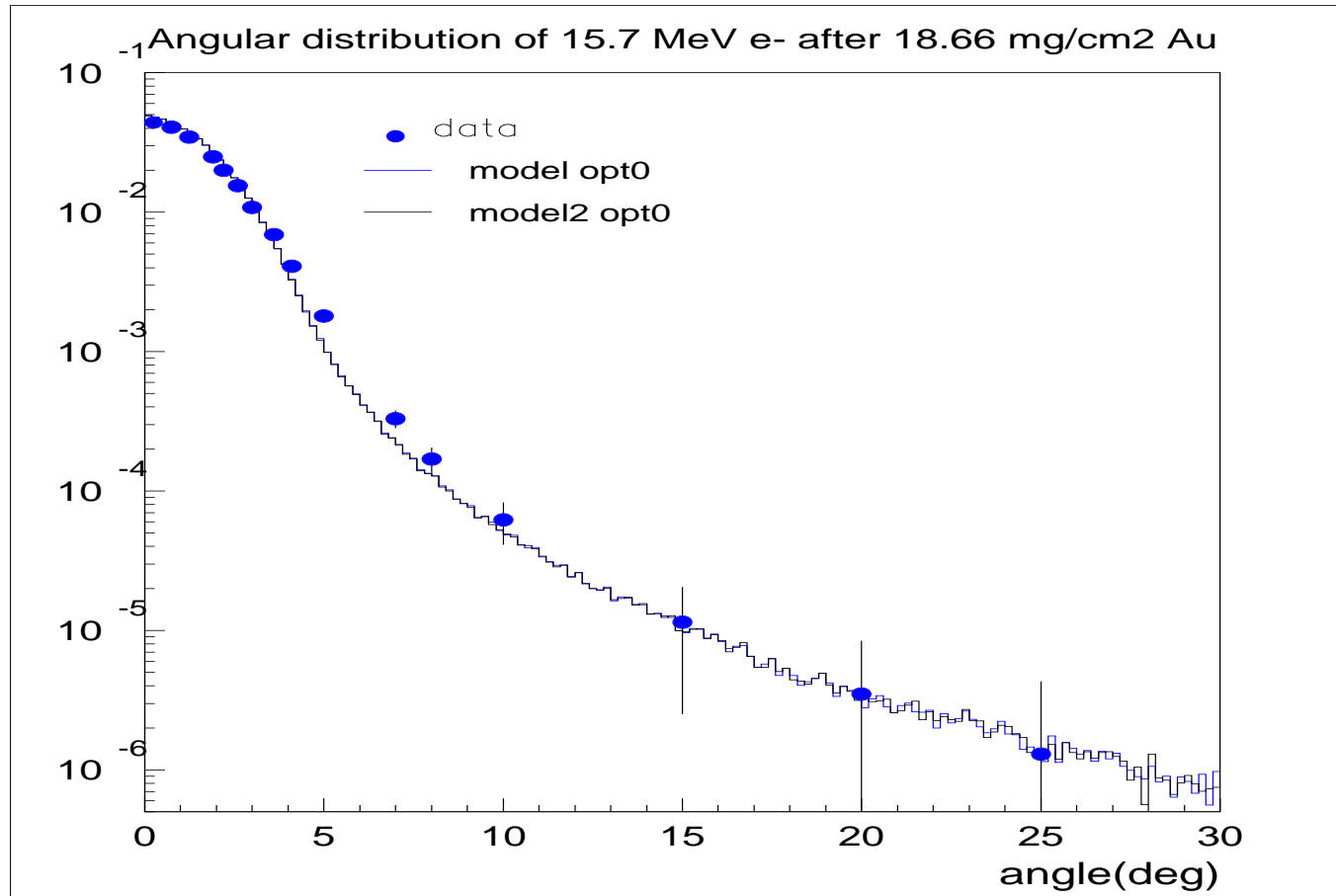
(dashed lines show the +- 1 σ limits)

8

e- scattering theta0 Geant4/data in %

G4UrbanMscModel2

- opt0 chi2=1.98
- opt3 chi2=5.51

9

e- scattering theta0 Geant4/data in %

opt 0

- ● model chi2=24.98
- ▲ model2 chi2=1.98

G4/data

Z

e- scattering theta0 Geant4/data in %

opt 3

● model chi2=17.13
▲ model2 chi2=5.51

Angular distribution of 15.7 MeV e- after 18.66 mg/cm2 Au

data

model opt0

model2 opt0

angle(deg)

Conclusions:

opt 3 is not so good as opt 0 (both models) , step depencence is not weak enough

opt 0 results:

central part of angle distributions is better in model2 (this is true for opt 3 as well but the difference is small)

tail is about the same for Au target in model/model2 **

tail is too small between 5 and 10 deg (and similar behaviour can be seen in the NRCC benchmark, see talk of Joseph Perl)

possible solution: parameter $\xi < 3$ instead of $\xi = 3$, ξ should be tuned too.

** this is not the case for Be, see next slide

Angular distribution of 15.7 MeV e- after 257 mg/cm2 Be

14