FLUKA Studies for the LHC Beam Scrapers

LCWG meeting, May 7th 2007

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Rationale

scrapers have to withstand a significant fraction of the beam halo (down to few sigmas)

possibility of being used in an emergency to ‘dump’ the beam?

choice of thickness, material, and speed

Outline

Study of different materials/thicknesses

- for a Gaussian tail above $3\sigma_x$
- for a low impact parameter
  [multiturn evaluation of the peak in the adiabatic assumption]

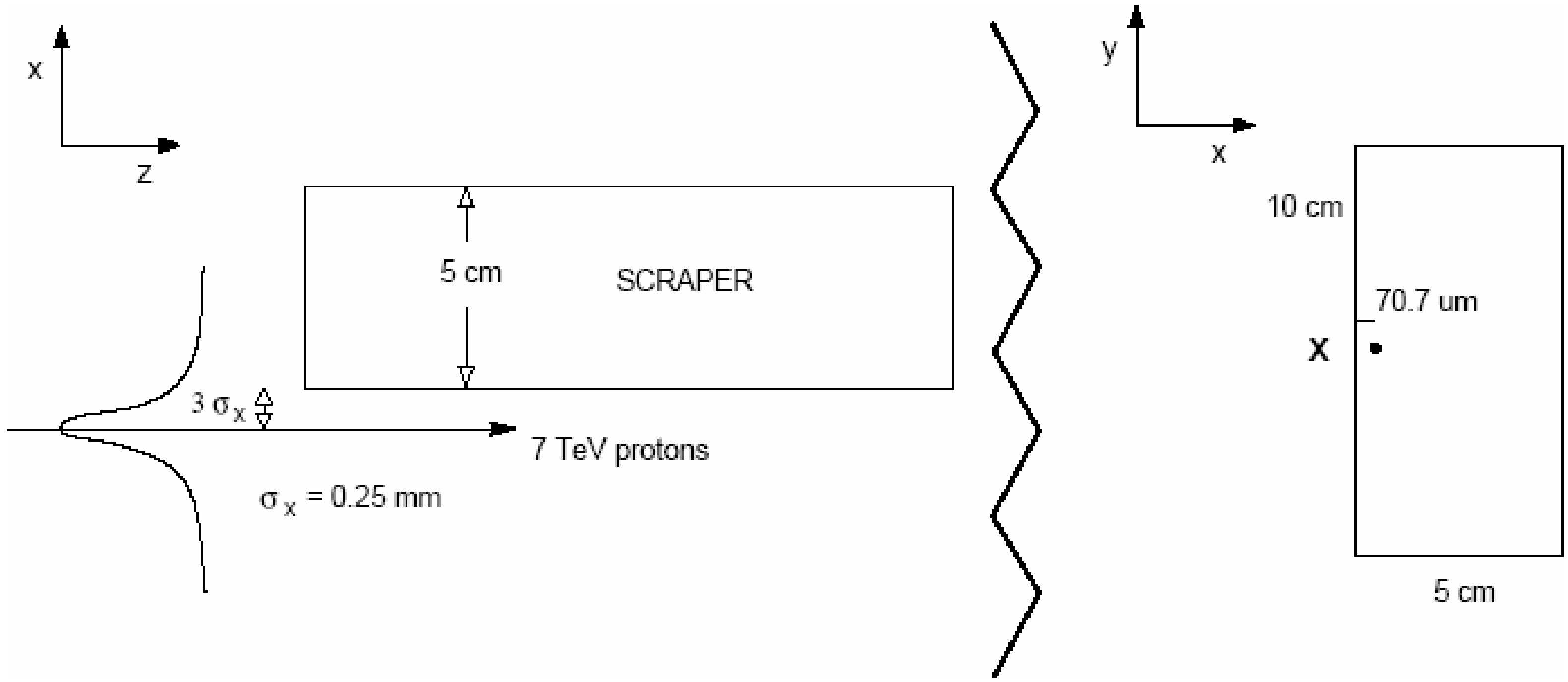
Short thickness (alignment accuracy)

Cu and W (spreading efficiency)

Huge ionization peak for tiny beam size

Total energy deposition per proton

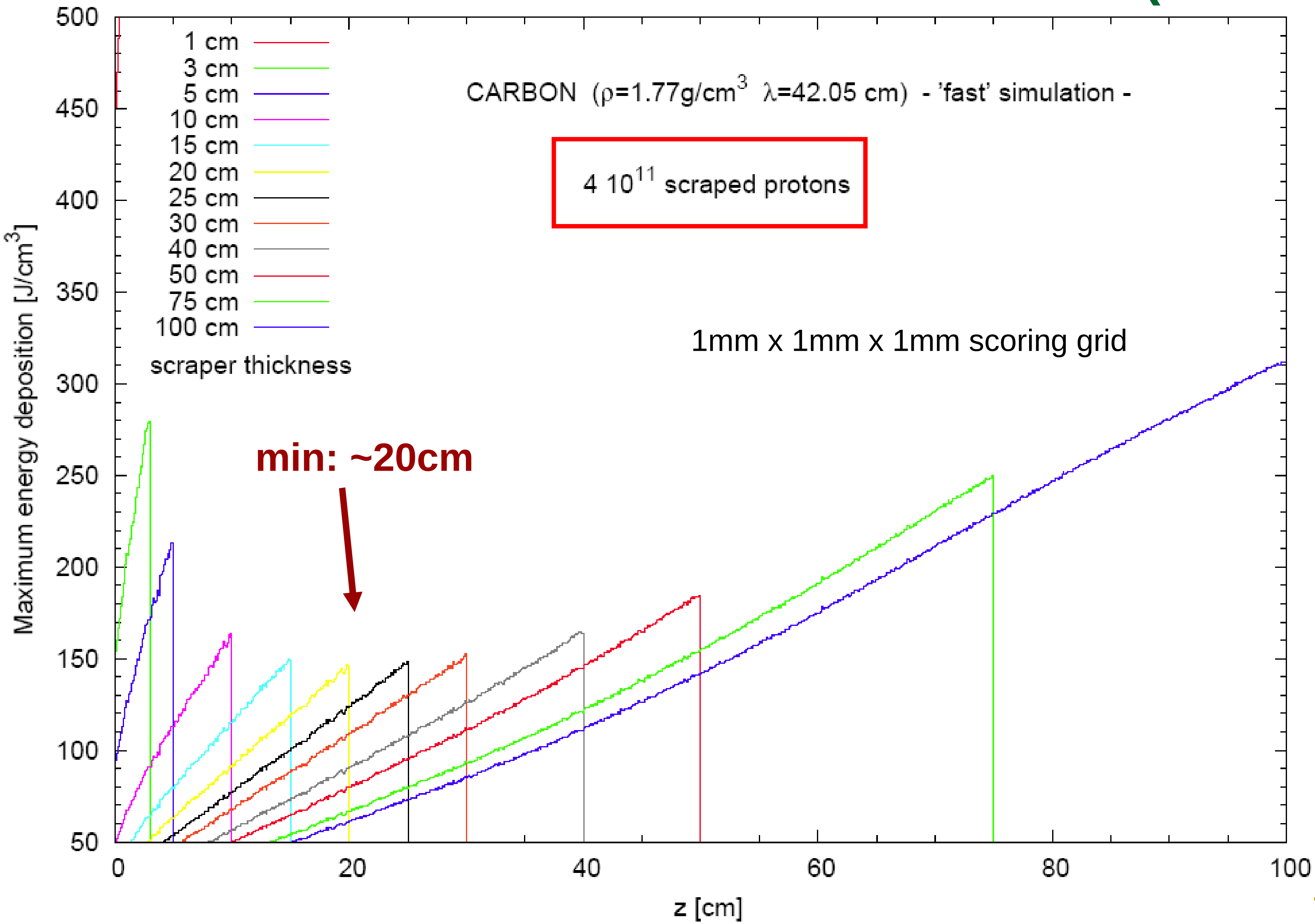
Scraper at rest at $3\sigma_x$ Gaussian beam tail



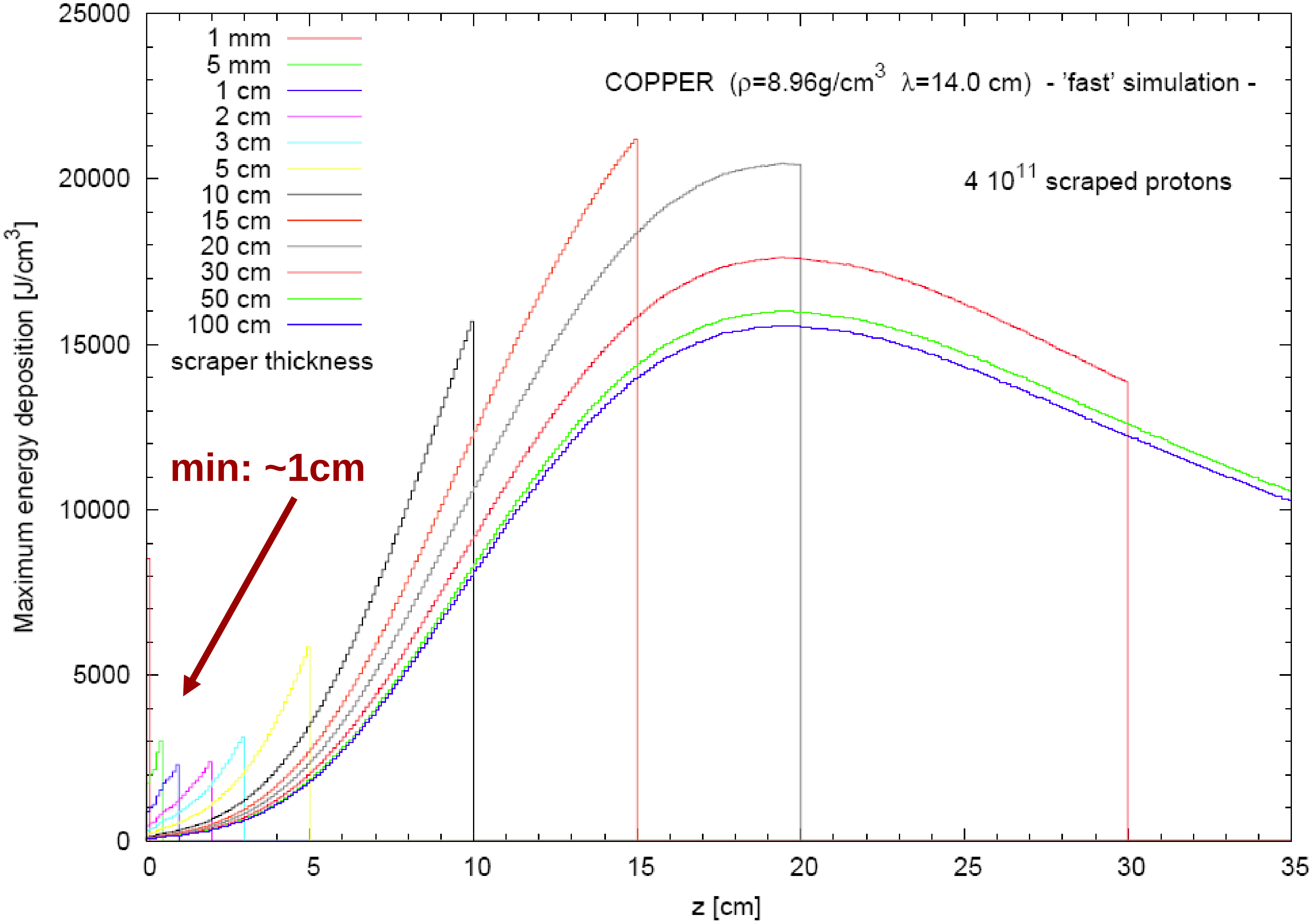
multiturn evaluation of energy deposition

$$
\begin{aligned}
E(x,y,z) &= N_p E_1(x,y,z) + N_p\left[\exp\left(-t/\lambda\right)\right]E_1(x,y,z) + N_p\left[\exp\left(-2t/\lambda\right)\right]E_1(x,y,z) + \\
&+ \ldots = N_p E_1(x,y,z)\sum_{n=0}^{\infty}\left[\exp\left(-t/\lambda\right)\right]^n = \\
&= N_p E_1(x,y,z)\left[1-\exp\left(-t/\lambda\right)\right]^{-1}
\end{aligned}
$$

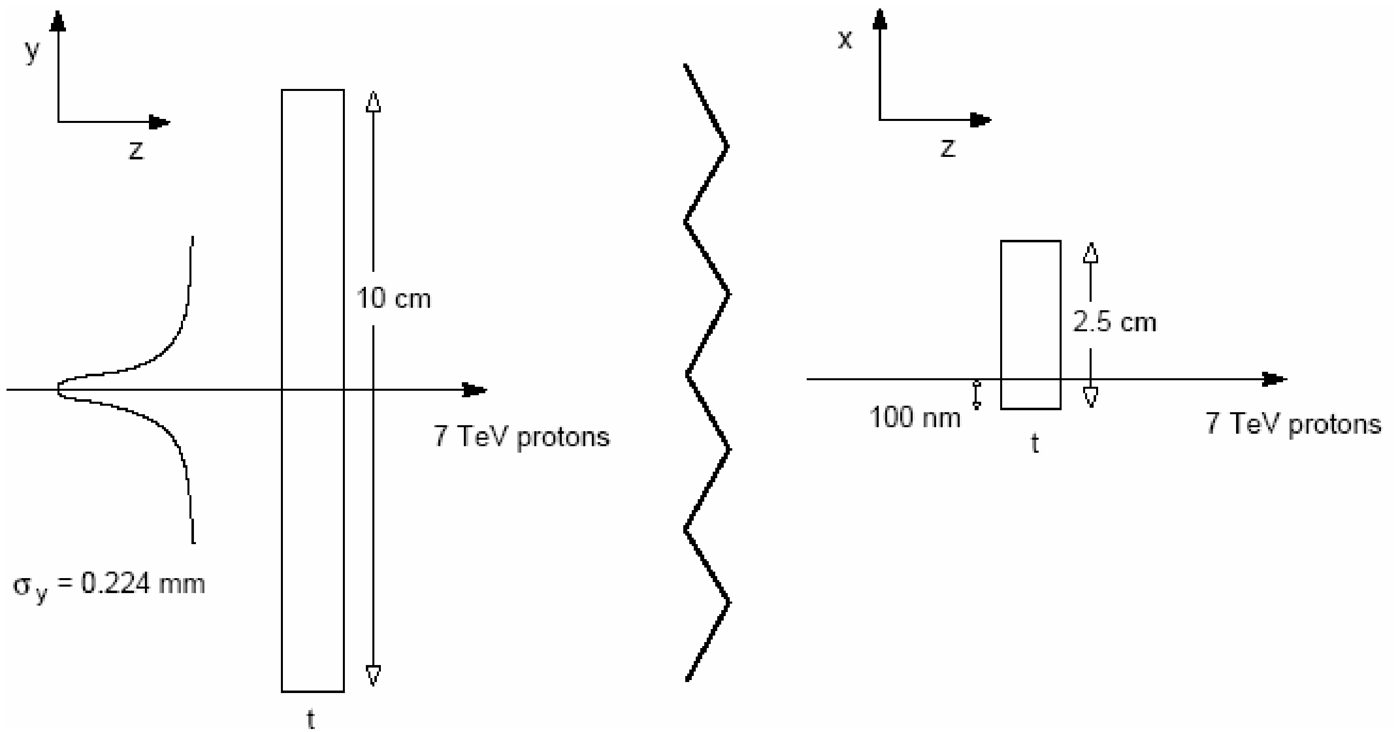
Carbon – Maximum Energy Deposition
(multiturn)



Copper – Maximum Energy Deposition
(multiturn)



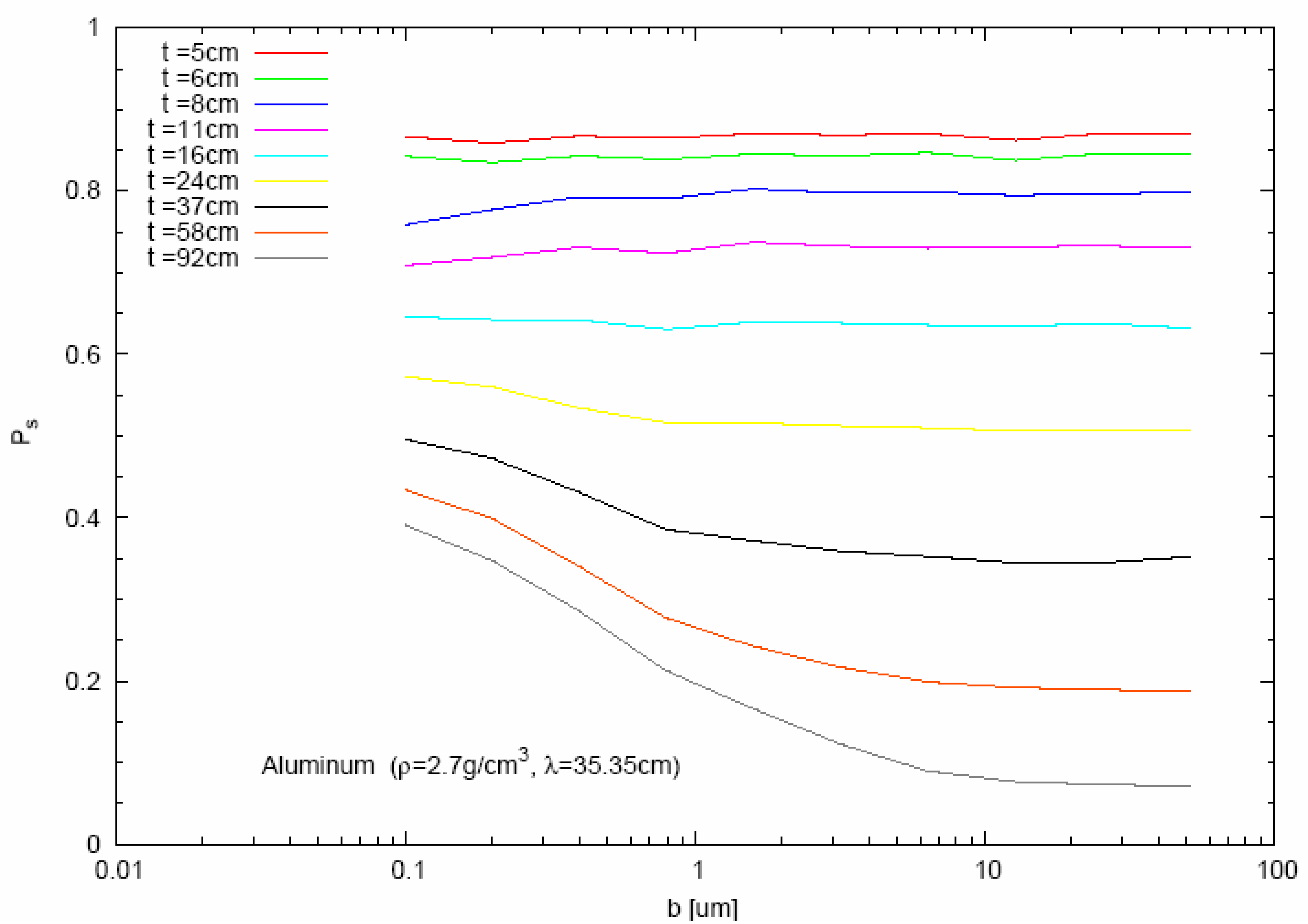
Scraper at rest pencil beam



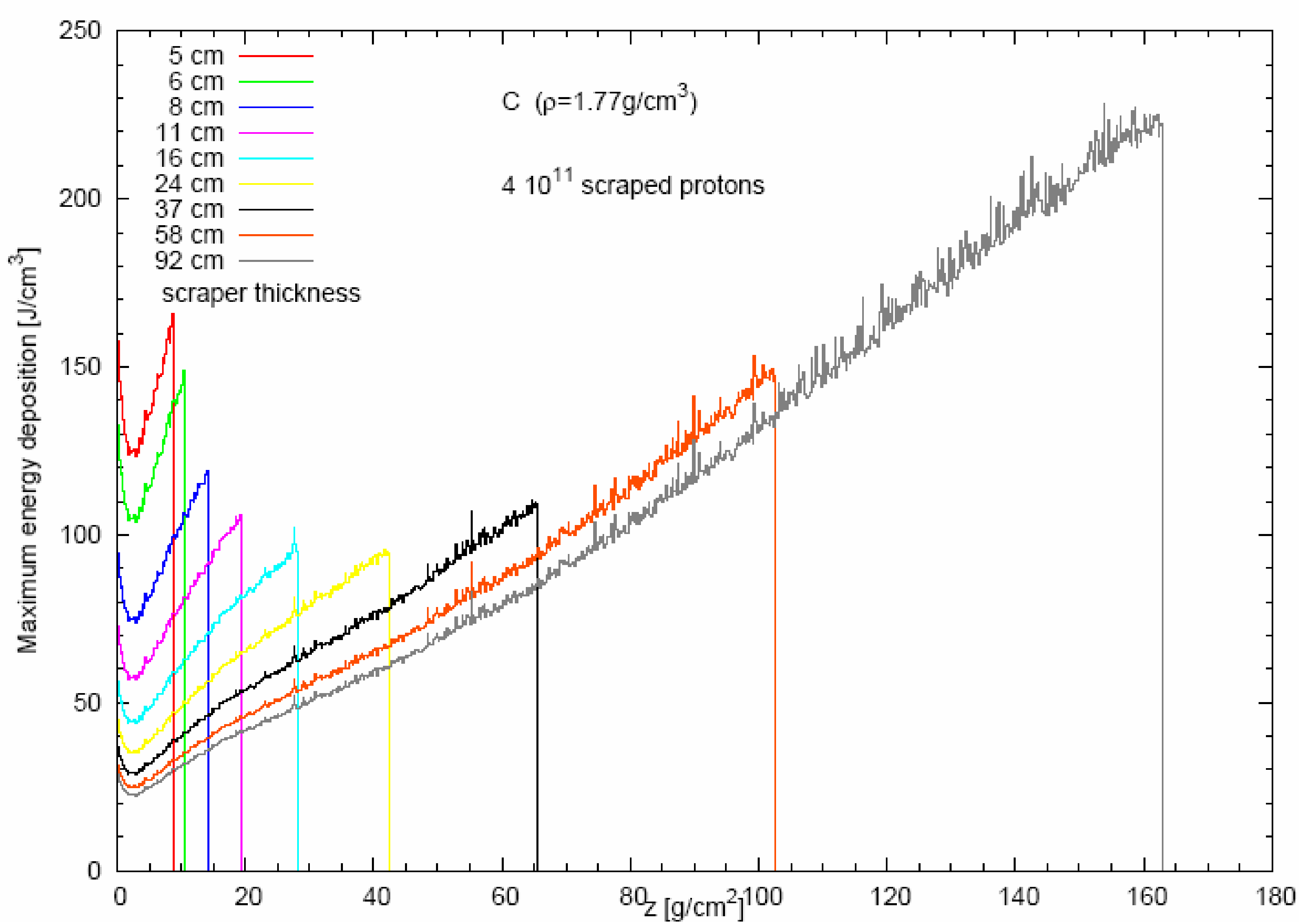
multiturn evaluation of energy deposition

$$E(x,y,z) = N_p E_1(x,y,z) + N_p P_s E_1(x,y,z) + N_p P_s{}^2 E_1(x,y,z) + \\ + \ldots = N_p E_1(x,y,z) \sum_{n=0}^{\infty} P_s{}^n = \\ = N_p E_1(x,y,z)\,[1 - P_s]^{-1}$$

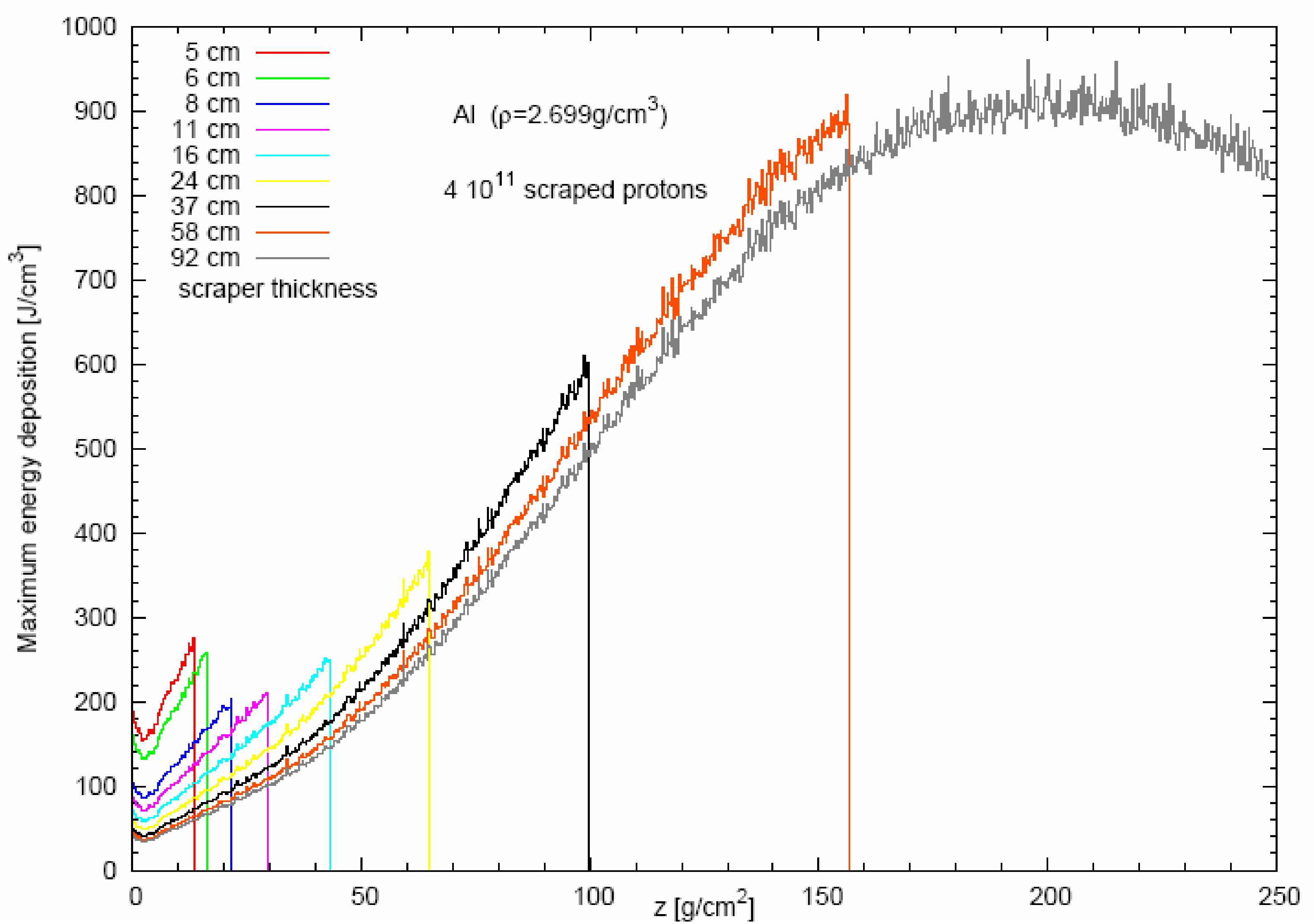
Survival probability vs impact parameter



Carbon – Maximum Energy Deposition (multiturn)

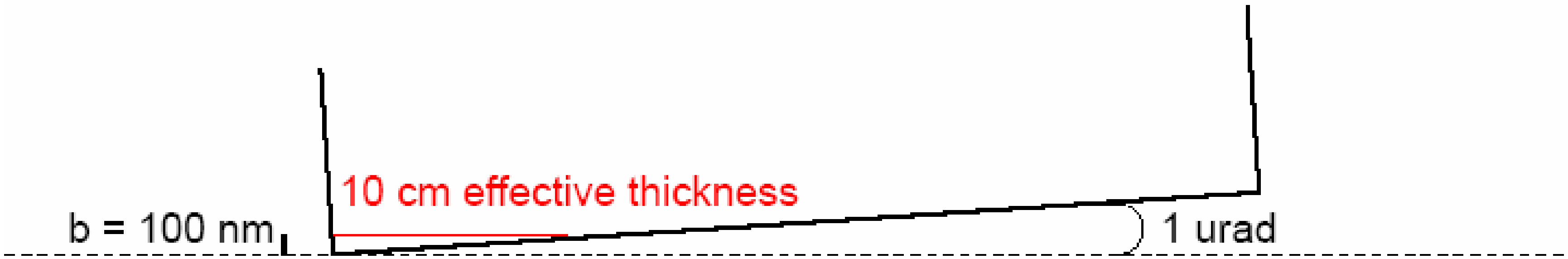


Aluminum – Maximum Energy Deposition (multiturn)

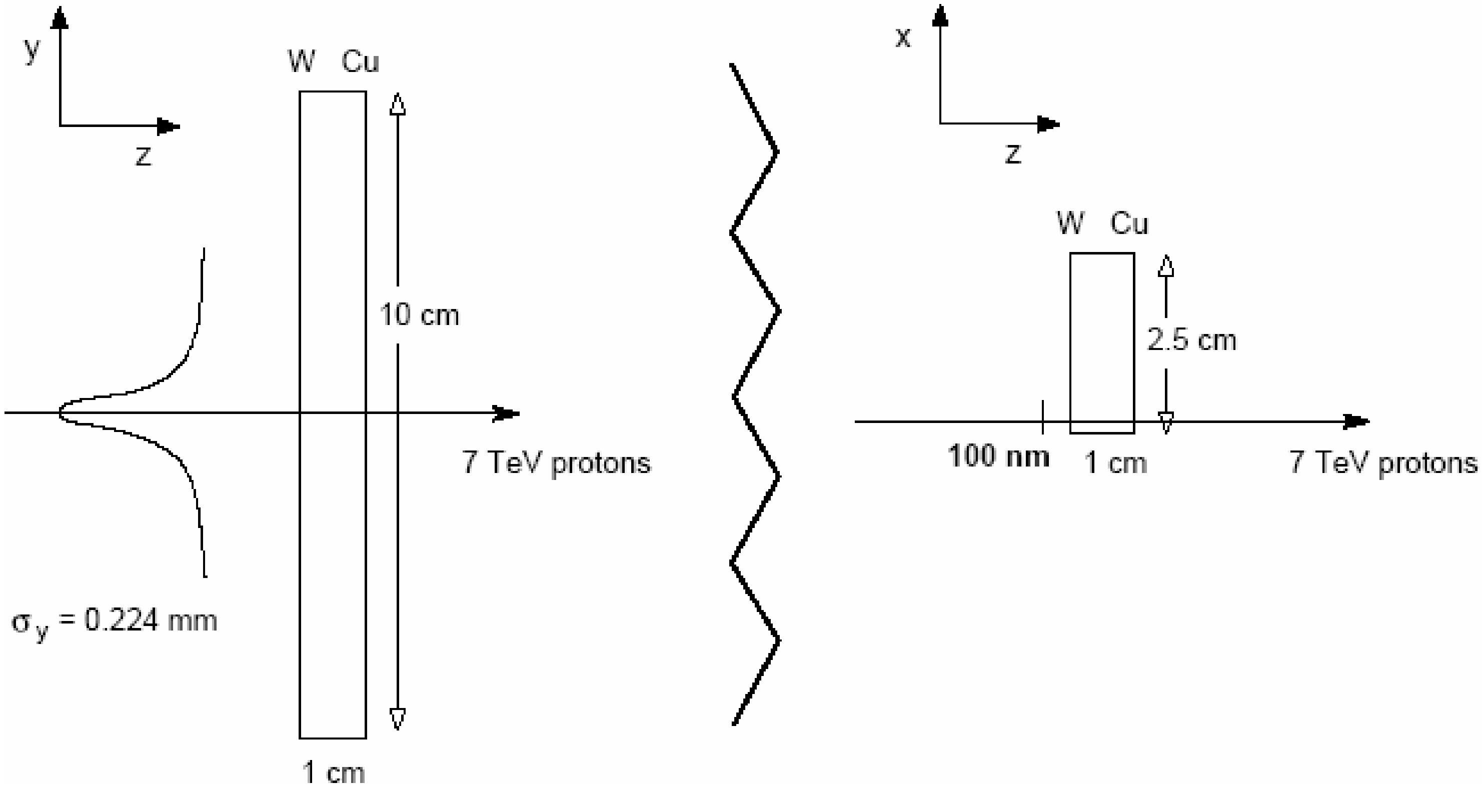


Alignment accuracy

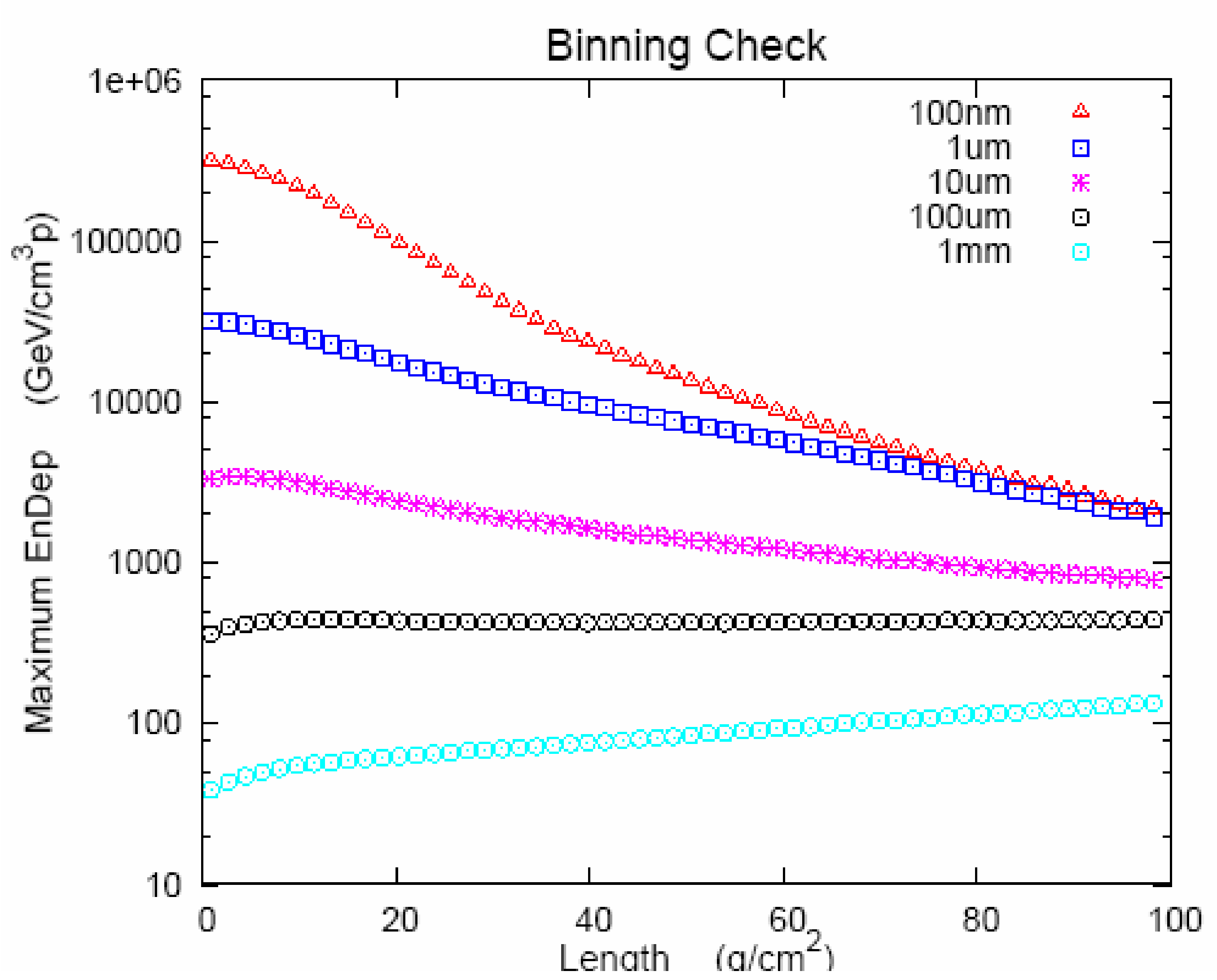
the discrepancy between the scraper thickness and the effective thickness becomes important at low impact parameters



rectangular x-profile

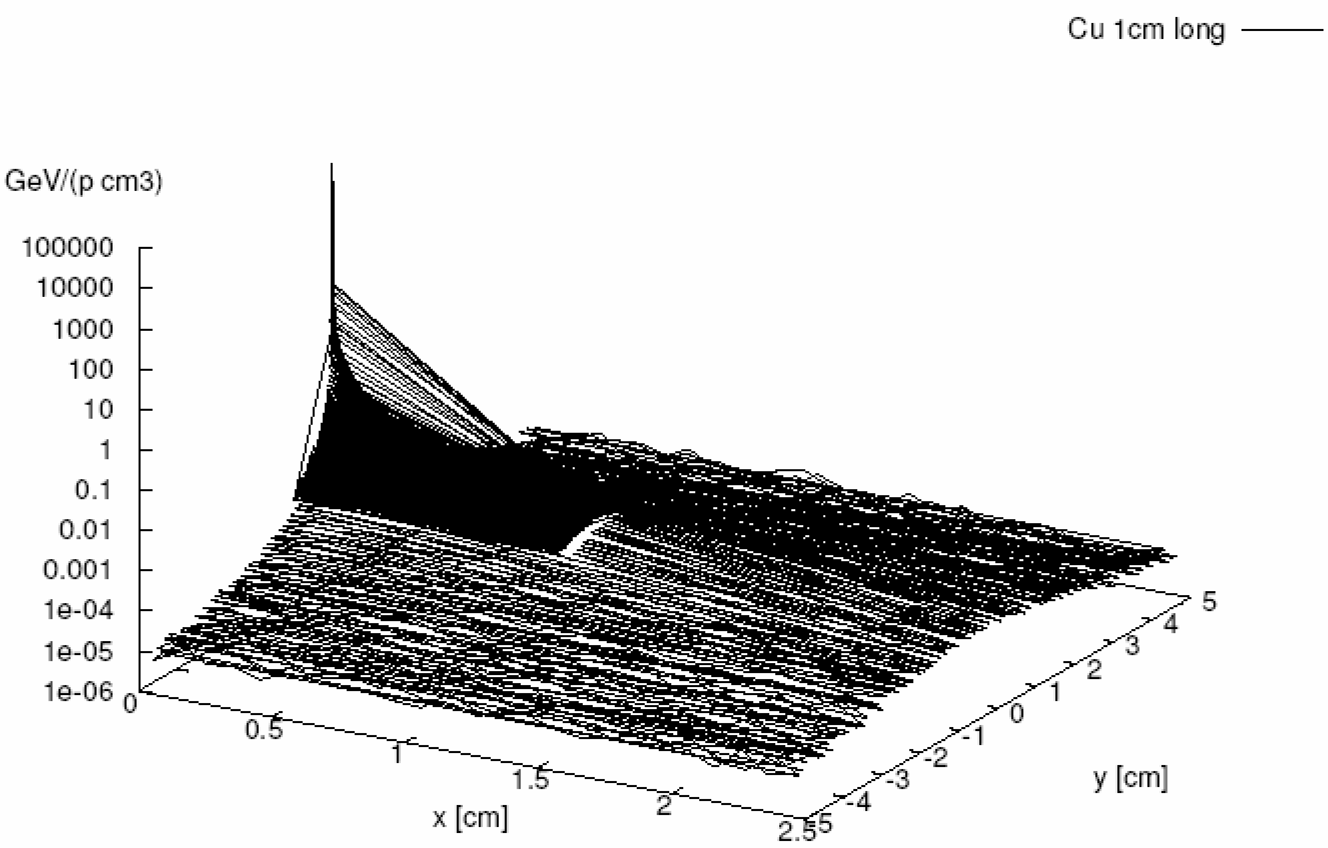


Beam size effect on the peak evaluation



Sectional energy deposition map

averaged over the 1 cm scraper thickness



Fitting function

$$f(x,y) = A\,\exp\left(-G(x-c)^2\right)\,\exp\left(-Fy^2\right) + B\,\frac{\exp\left(-G(x-c)^2\right)}{(1+(x-C)^2/D^2)}\,\frac{\exp\left(-Fy^2\right)}{(1+y^2/E^2)}$$

$A = 29.7$

$B = 53412$

$C = 3.3357\ 10^{-6}$

$D = 1.2238\ 10^{-6}$

$E = 0.03155$

$F = 63.644$

$G = 51034$

x, y [cm] $\quad f(x,y)$ [GeV/(p cm^3)]

reasonably preserving:

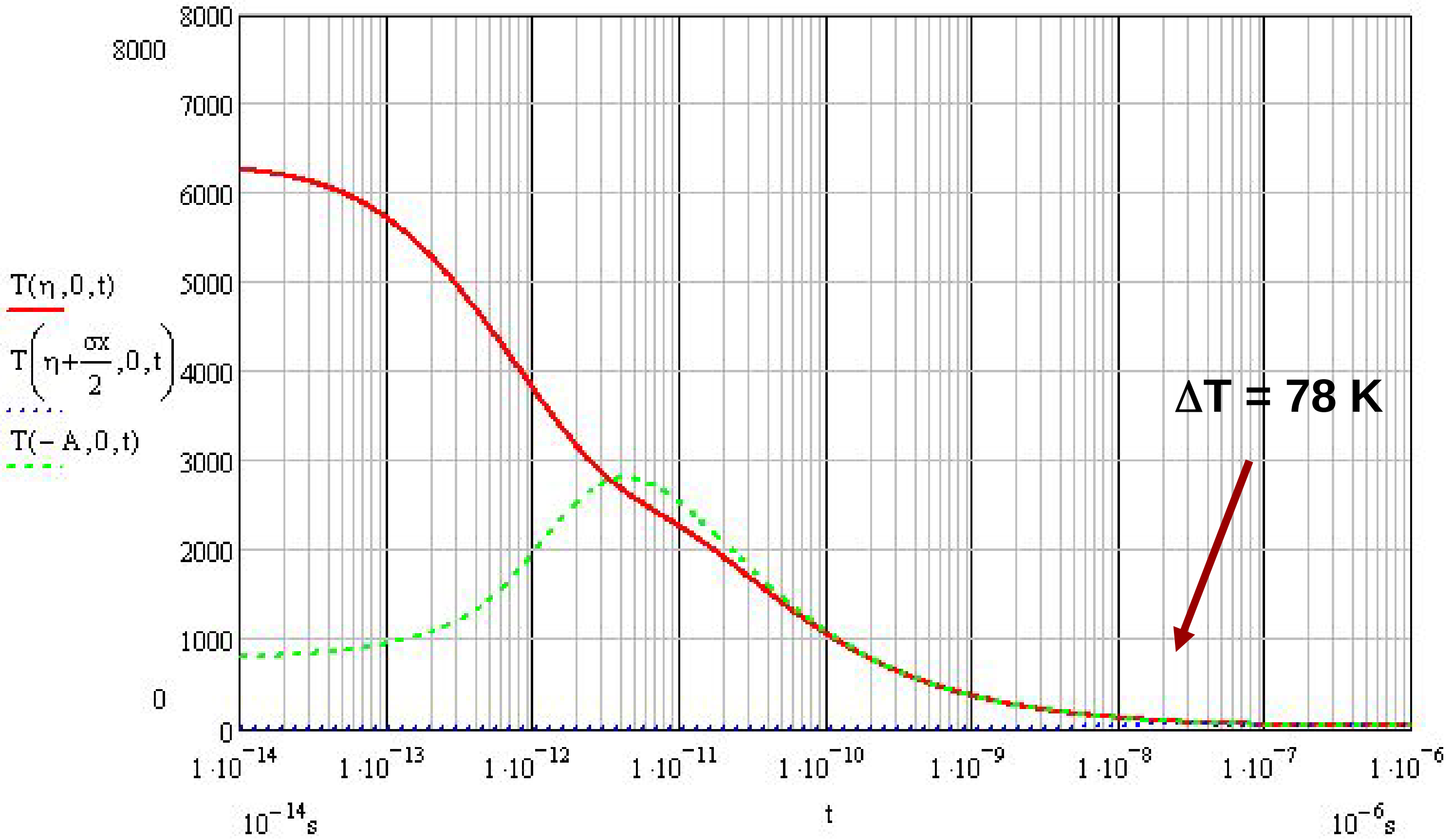
1. the peak (18.8 vs the original 19.3 TeV/(cm3*p))

2. the integral over the peak bin (100nm x 100nm x 1cm) (1.71 vs 1.93 keV/p)

3. the integral over the peak region (0<x<0.1mm,-0.35<y<0.35mm, 0<z<1cm) (17.3 vs 16.4 MeV/p).

4. the integral over the full scraper (40 vs 33 MeV/p)

Heat diffusion over a bunch time scale



Cu

assuming the number of protons per bunch above $2\sigma_x$

(the whole Gaussian tail concentrated on 100nm)

A. Bertarelli

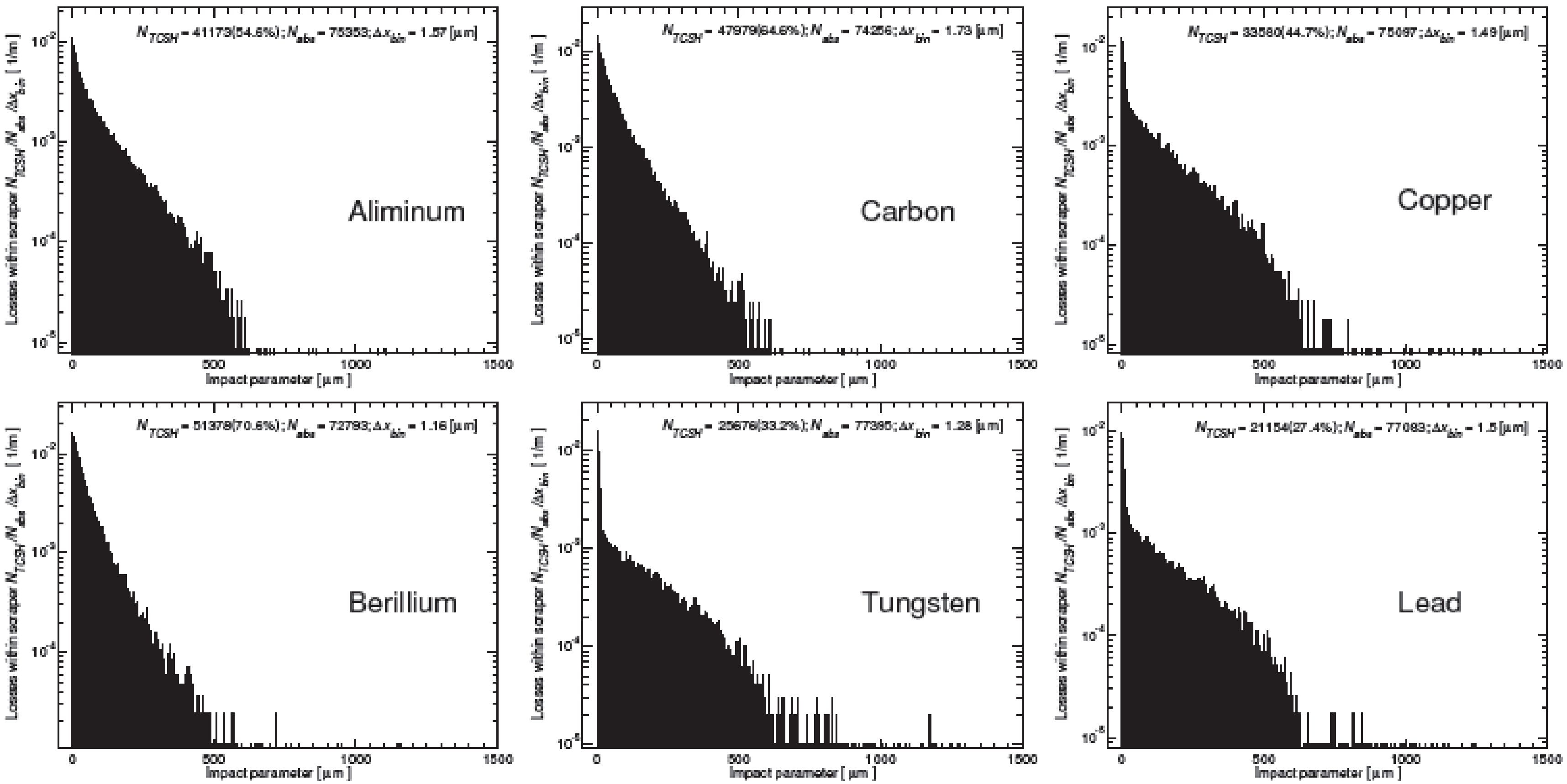
Total energy deposition per proton

scraper thickness	Cu	W
[mm]	[MeV/p]	
0.1	0.160	0.386
0.5	0.866	2.208
1	1.841	4.871
5	12.396	42.043
10	32.782	165.987

Conclusions

- How to reduce the heat load on the scraper edge due to bunch piling up? (How low the scraper speed has to be?)
- Distributions of *impinging* (including coming back) protons are needed for a more realistic sampling. (Their integral gives also the normalization factor for cooling requirements)
- *Loss* maps in the scrapers are useful for the evaluation of the impact on the warm/cold section elements (later!)

Scraper loss maps



1 mm/s scraper speed

S. Redaelli