PTRAN

McPTRAN.MEDIA, McPTRAN.CAVITY & McPTRAN.RZ

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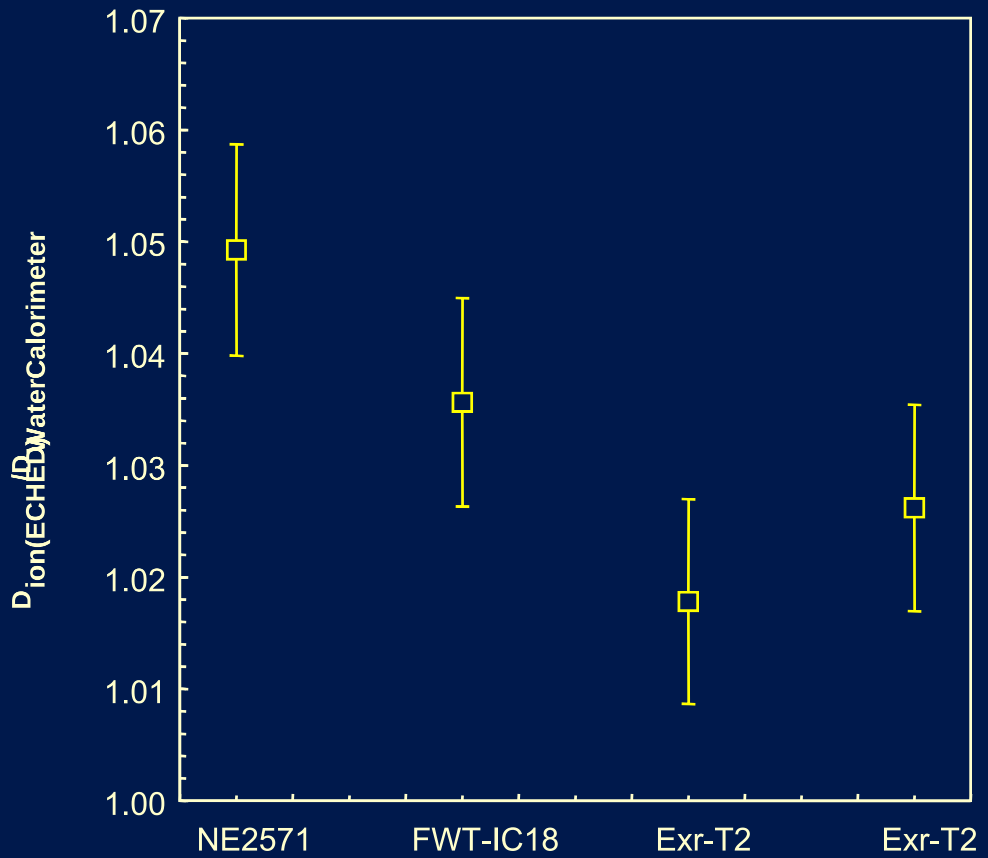
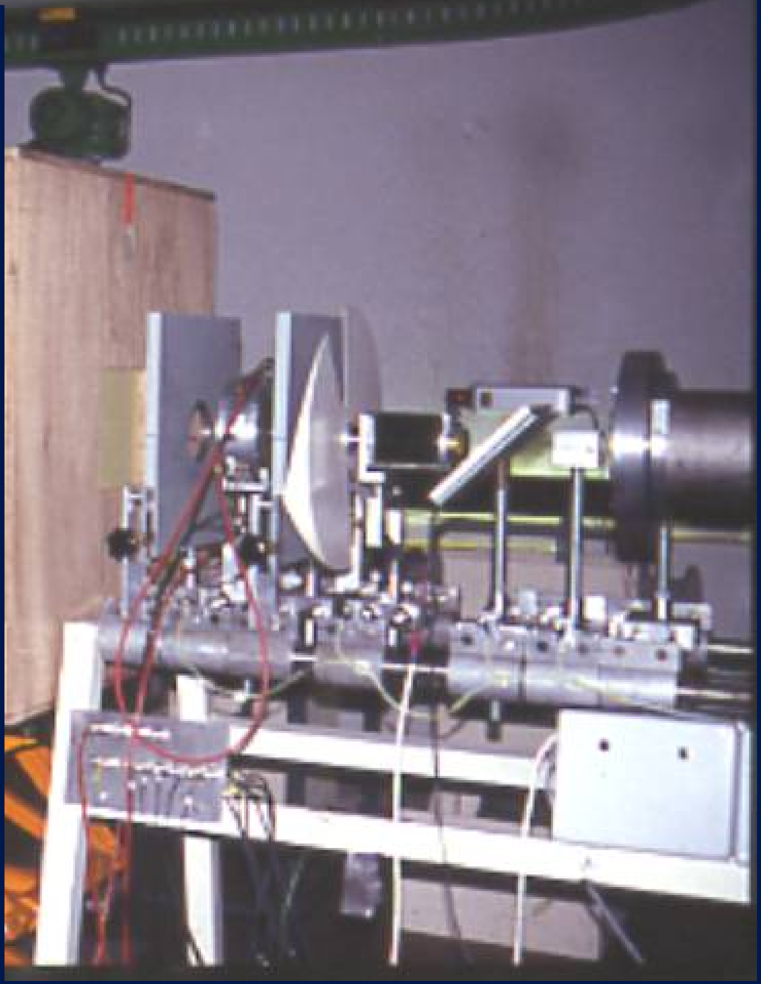
Why PTRAN?

Louvain-la-Neuve 1994





Why PTRAN here?

- Incidental remark
- Order out of chaos:
  - McPTRAN.MEDIA
  - McPTRAN.CAVITY (&McPTRAN.CHAMBER)
  - McPTRAN.RZ
- Illustrative

PTRAN

- Martin Berger 1993 (NISTIR 5113)
- Available through NEA, RSICC
- Designed for calculation of dose distributions in water

PTRAN: pre-calculated grid

$T_0\ \delta s_0\ f_V(\lambda)_0$ σ_{nuc0}

$f_M(\vartheta)_0$

$T_1\ \delta s_1\ f_V(\lambda)_1$ σ_{nuc1}

$f_M(\vartheta)_1$

$T_2\ \delta s_2\ f_V(\lambda)_2$ σ_{nuc2}

$f_M(\vartheta)_2$

…

$T_n\ \delta s_n\ f_V(\lambda)_n$ σ_{nucn}

$f_M(\vartheta)_n$

$\longrightarrow$

$E_0\ s_0\ x_0\ y_0\ z_0\ \theta_0\ \varphi_0$

$E_1\ s_1\ x_1\ y_1\ z_1\ \theta_1\ \varphi_1\ W_1$

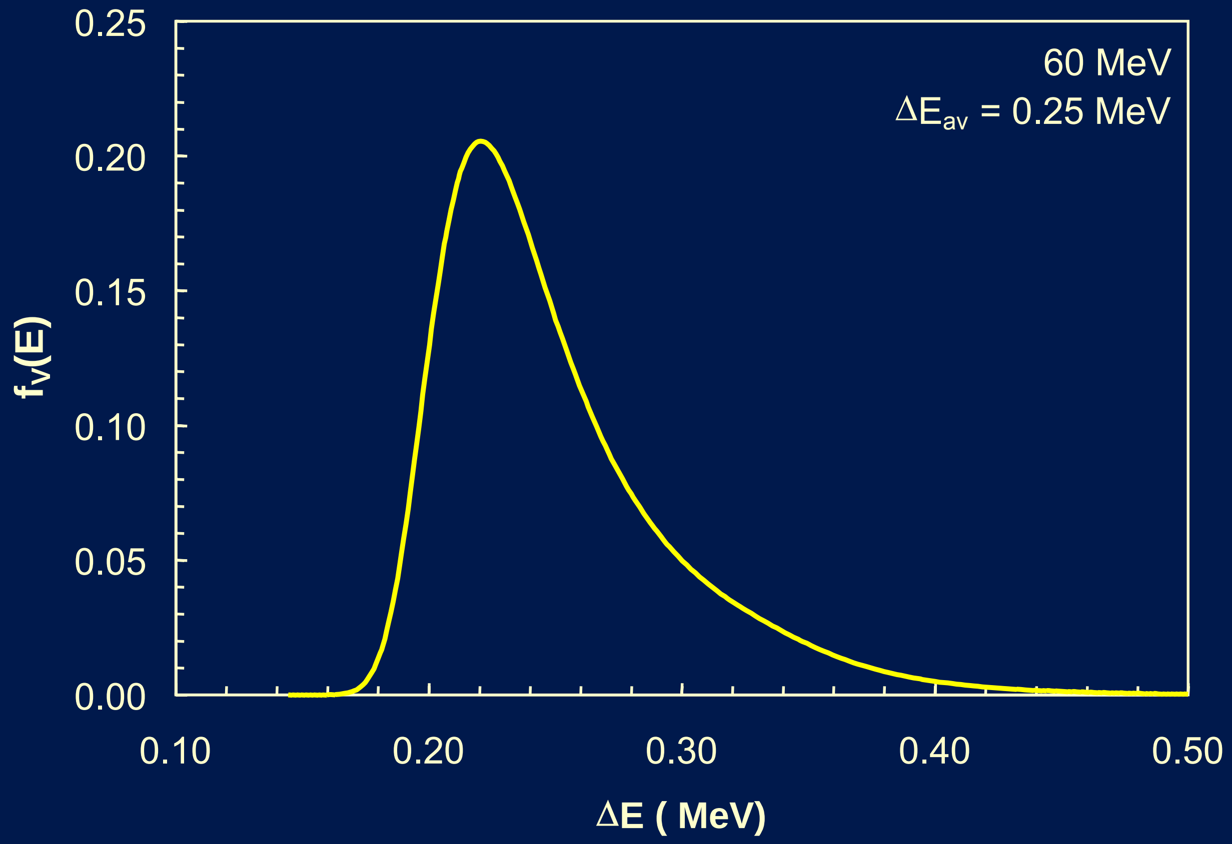
$E_2\ s_2\ x_2\ y_2\ z_2\ \theta_2\ \varphi_2\ W_2$

…

$E_n\ s_n\ x_n\ y_n\ z_n\ \theta_n\ \varphi_n\ W_n$

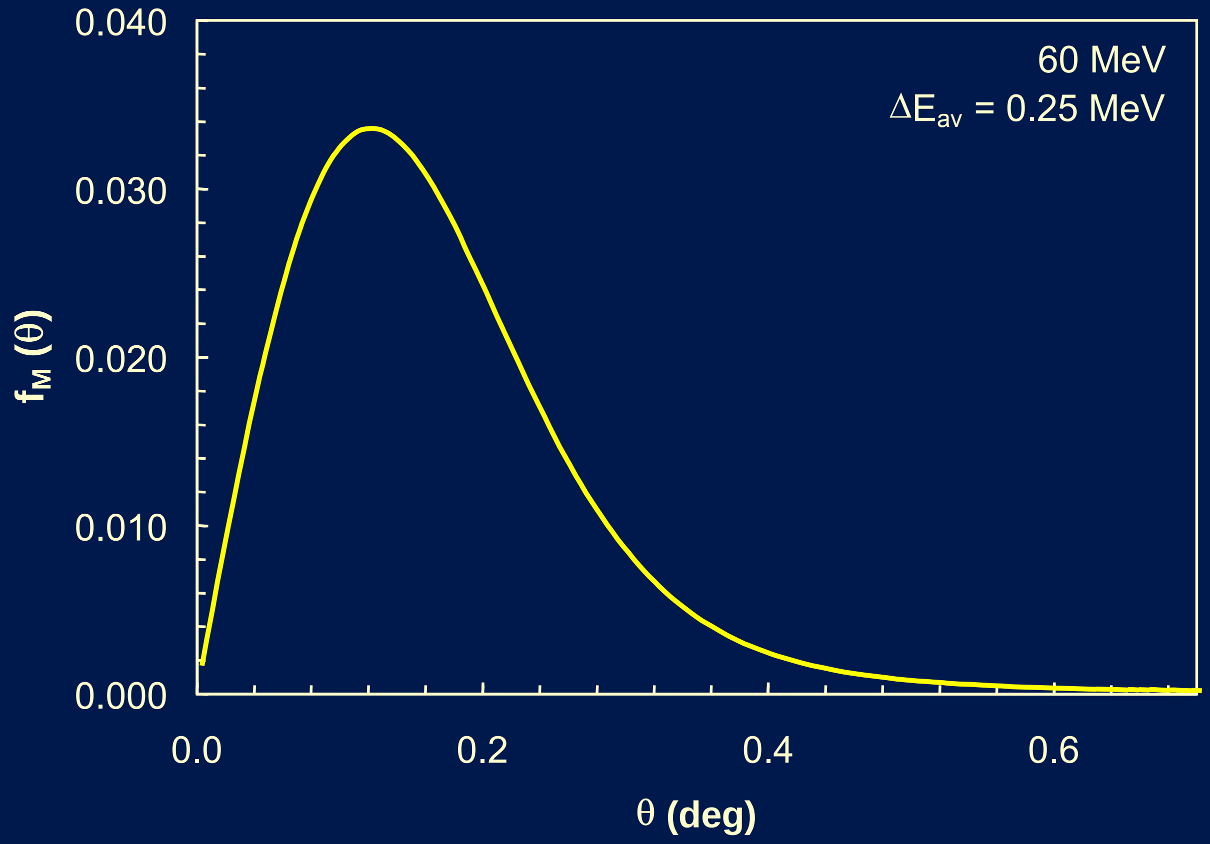
PTRAN: energy straggling

- Vavilov

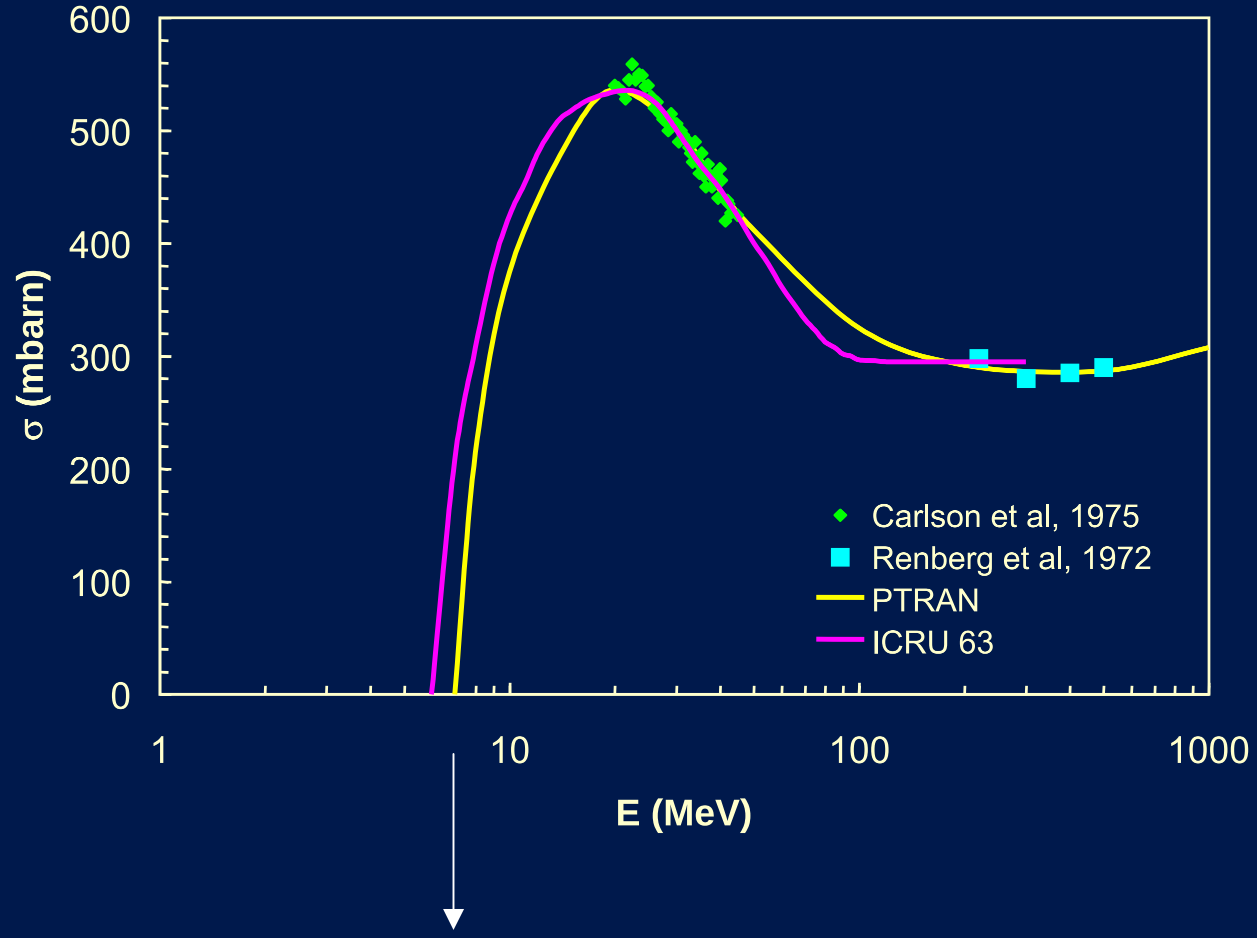


PTRAN: multiple scattering

- Molière



PTRAN: Total inelastic nuclear interaction cross sections



Theoretical threshold (Selzer, 1993)

PTRAN: preparatory programs

- PARAM
  - Parameters for Molière and Vavilov
  - Path lengths in CSDA
  - Nuclear attenuation coefficients
- VPREP: Vavilov distribution
- MPREP: Molière distribution

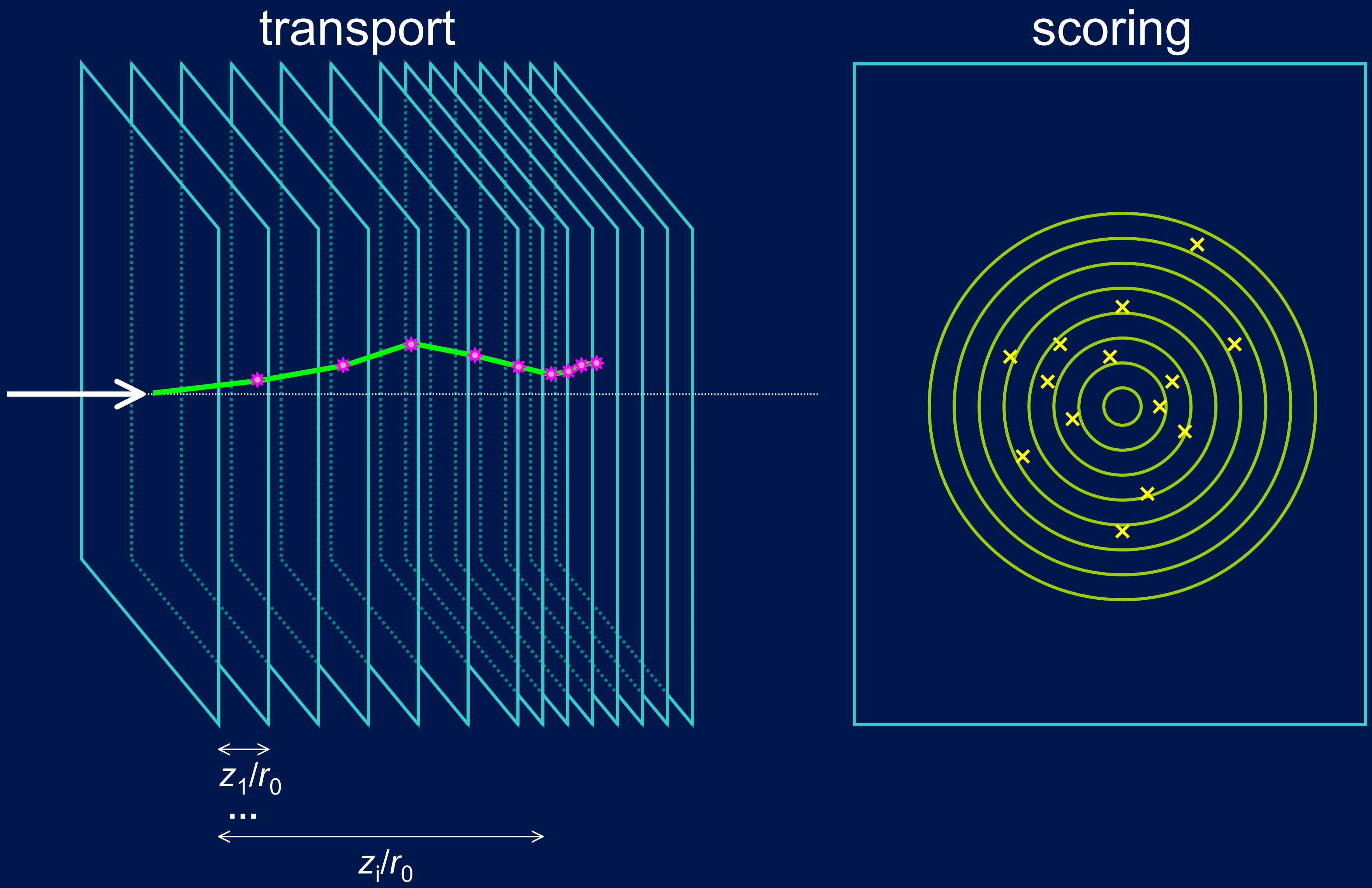
PTRAN: transport algorithm

- $(x_0,y_0,z_0) = (0,0,0)$; $(u_0,v_0,w_0) = (0,0,1)$
- E_0 is only parameter
- $E_n – E_{n-1}$ from Vavilov at nearest T_i
- Δs_n by interpolation
- θ' from Molière at $[T_i,T_{i+1}]$ & φ' uniform between -180 and +180 degrees.
- (θ',φ') transformed to (θ,φ) using [R]
- $\Delta x',\Delta y',\Delta z'$ calculated
- $\Delta x',\Delta y',\Delta z'$ transformed to $\Delta x,\Delta y,\Delta z$ using [R]
- Stop when $E_n < E_{cut}$ or $E_n < E_{fin}$ and dump E_n

PTRAN: random generator

- Default = congruential generator, period 2^{28}
- Optional: Lagged Fibonacci (Marsaglia-Zaman, 1987) period 2^{144}

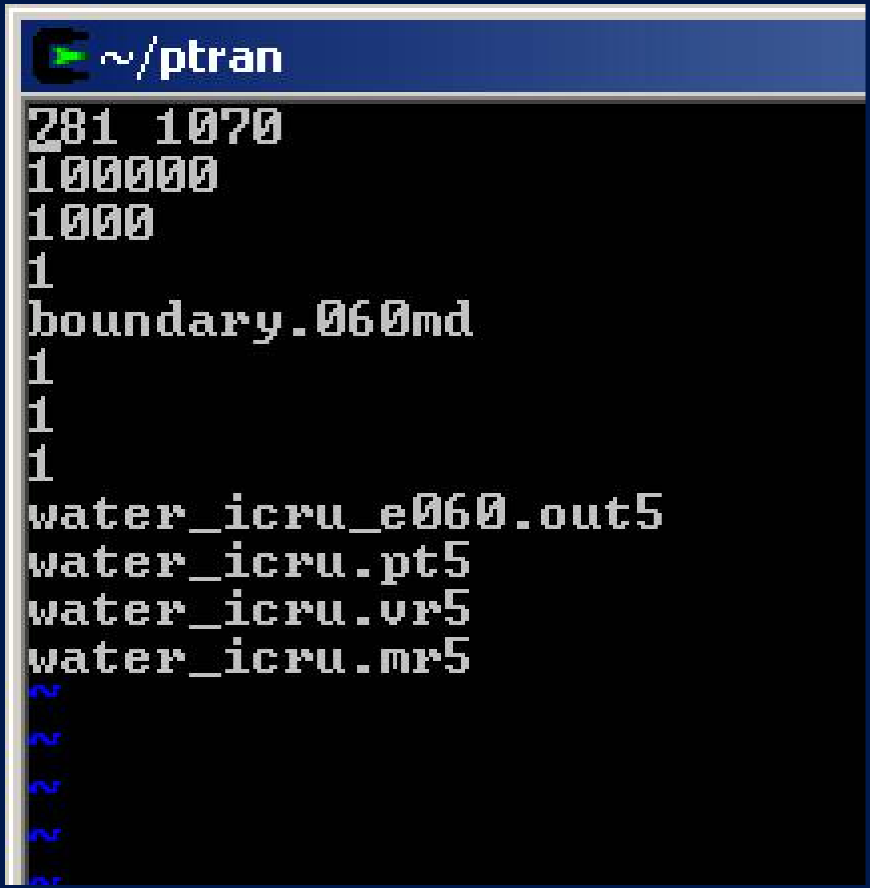
PTRAN: scoring geometry



PTRAN: scoring

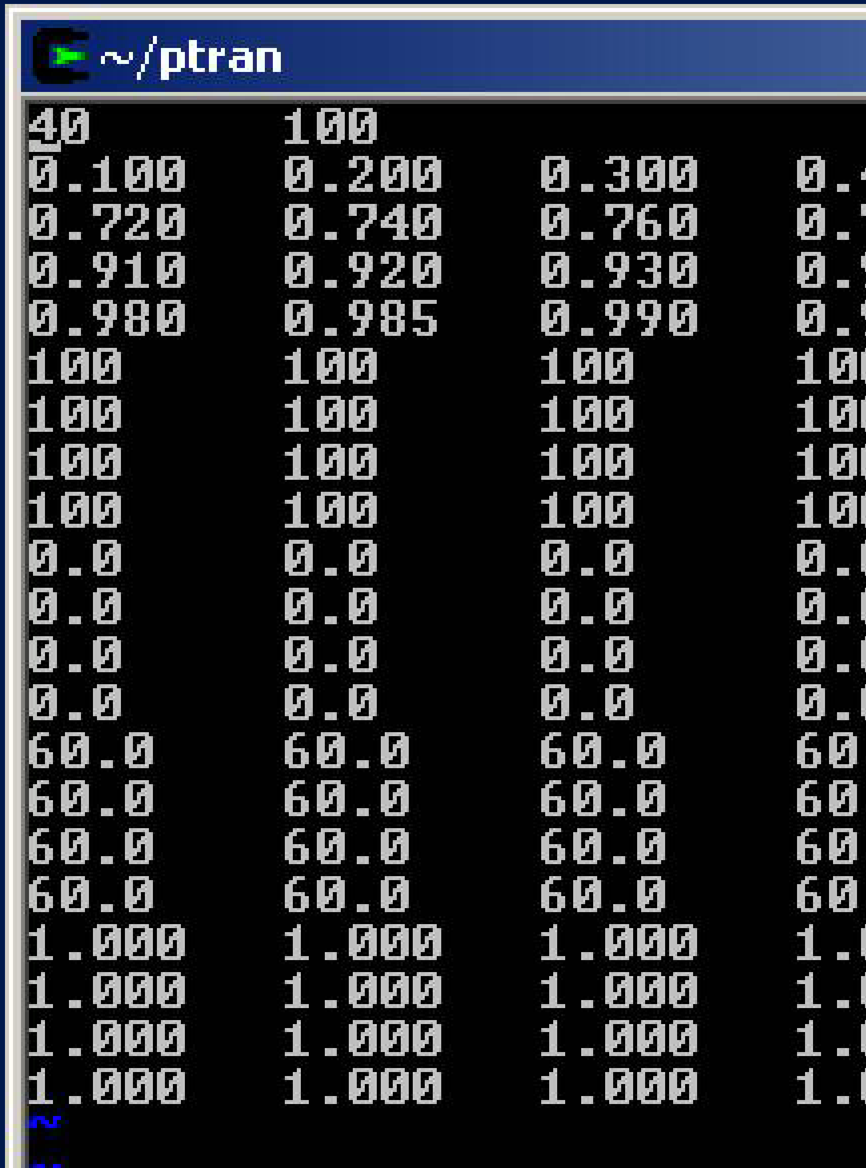
- $(dE/dz)_C$, estimated as
  $(S/\rho)_{cross} \cdot W_{cross} / \cos\theta_{cross}$
- $(dE/dz)_N$, estimated as
  $E_{cross} \cdot \mu_{cross} \cdot W_{cross} / \cos\theta_{cross}$
- Φ estimated as
  $1/\cos\theta_{cross}$
- Spectral distribution of Φ and radial distribution of $(dE/dz)_C$

Input file



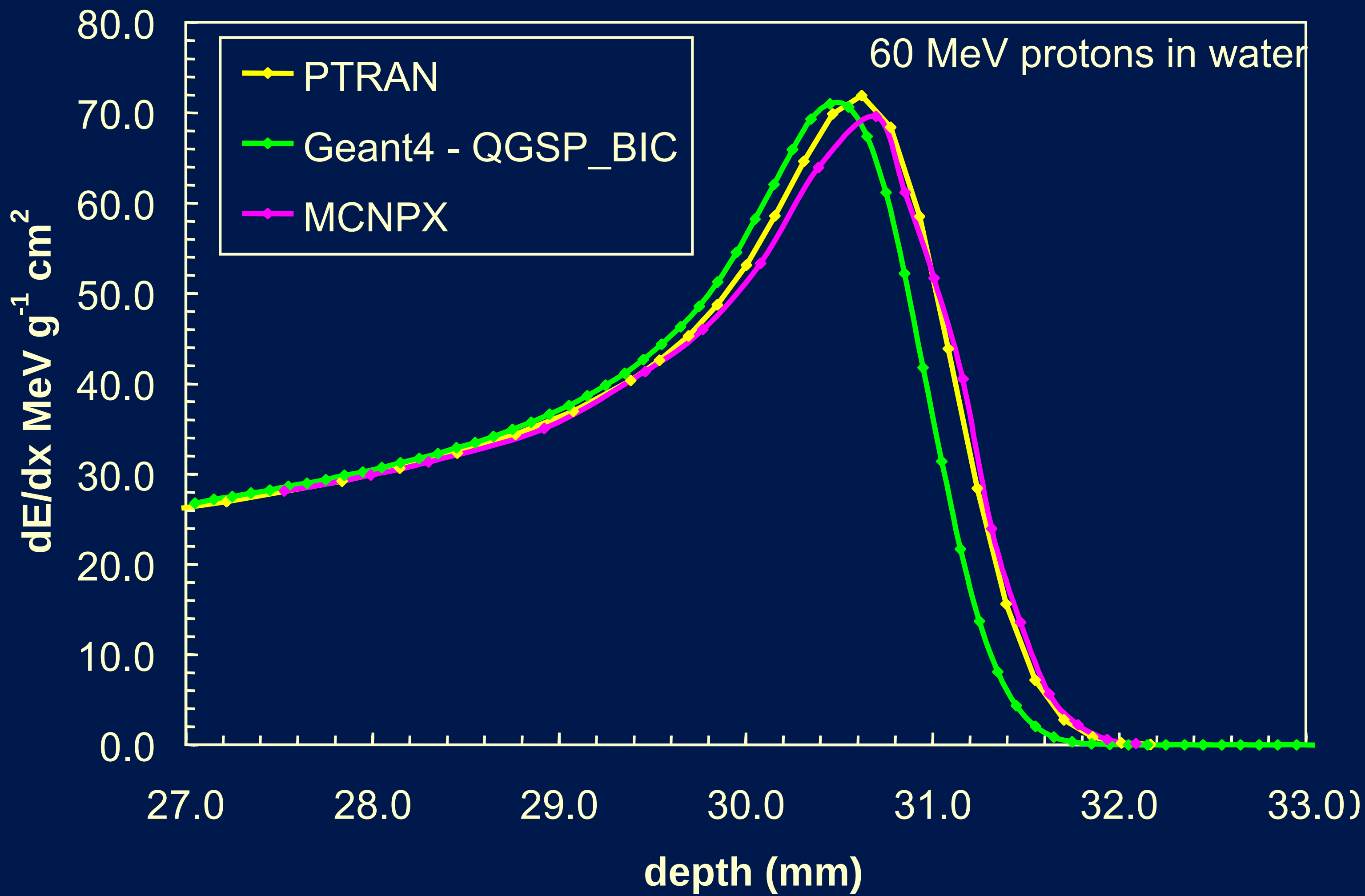
```
~/ptran
281 1070
100000
1000
1
boundary.060md
1
1
1
water_icru_e060.out5
water_icru.pt5
water_icru.vr5
water_icru.mr5
```

Boundary file

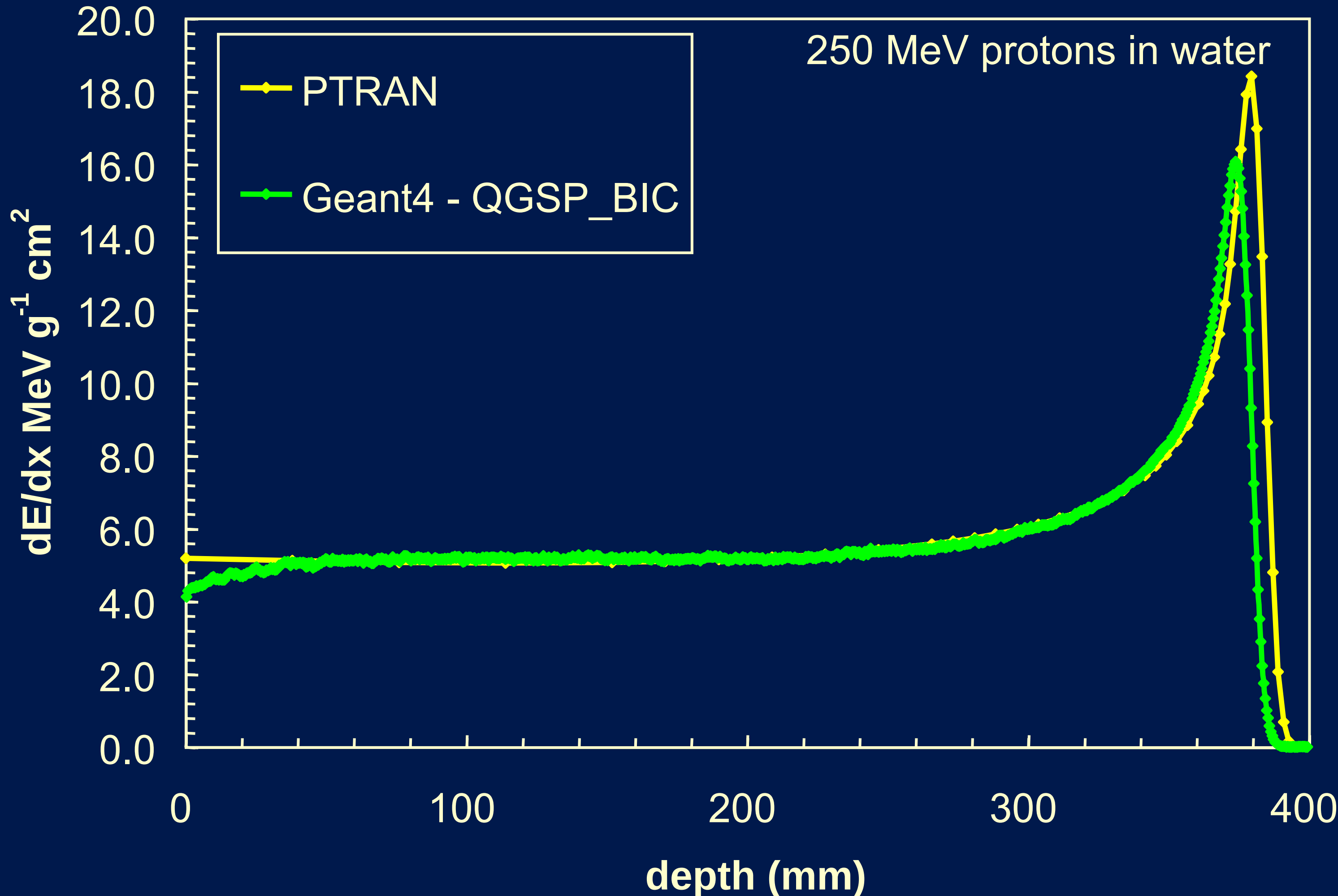


```
~/ptran
40       100
0.100    0.200    0.300
0.720    0.740    0.760
0.910    0.920    0.930
0.980    0.985    0.990
100      100      100
100      100      100
100      100      100
100      100      100
0.0      0.0      0.0
0.0      0.0      0.0
0.0      0.0      0.0
0.0      0.0      0.0
60.0     60.0     60.0
60.0     60.0     60.0
60.0     60.0     60.0
60.0     60.0     60.0
1.000    1.000    1.000
1.000    1.000    1.000
1.000    1.000    1.000
1.000    1.000    1.000
```

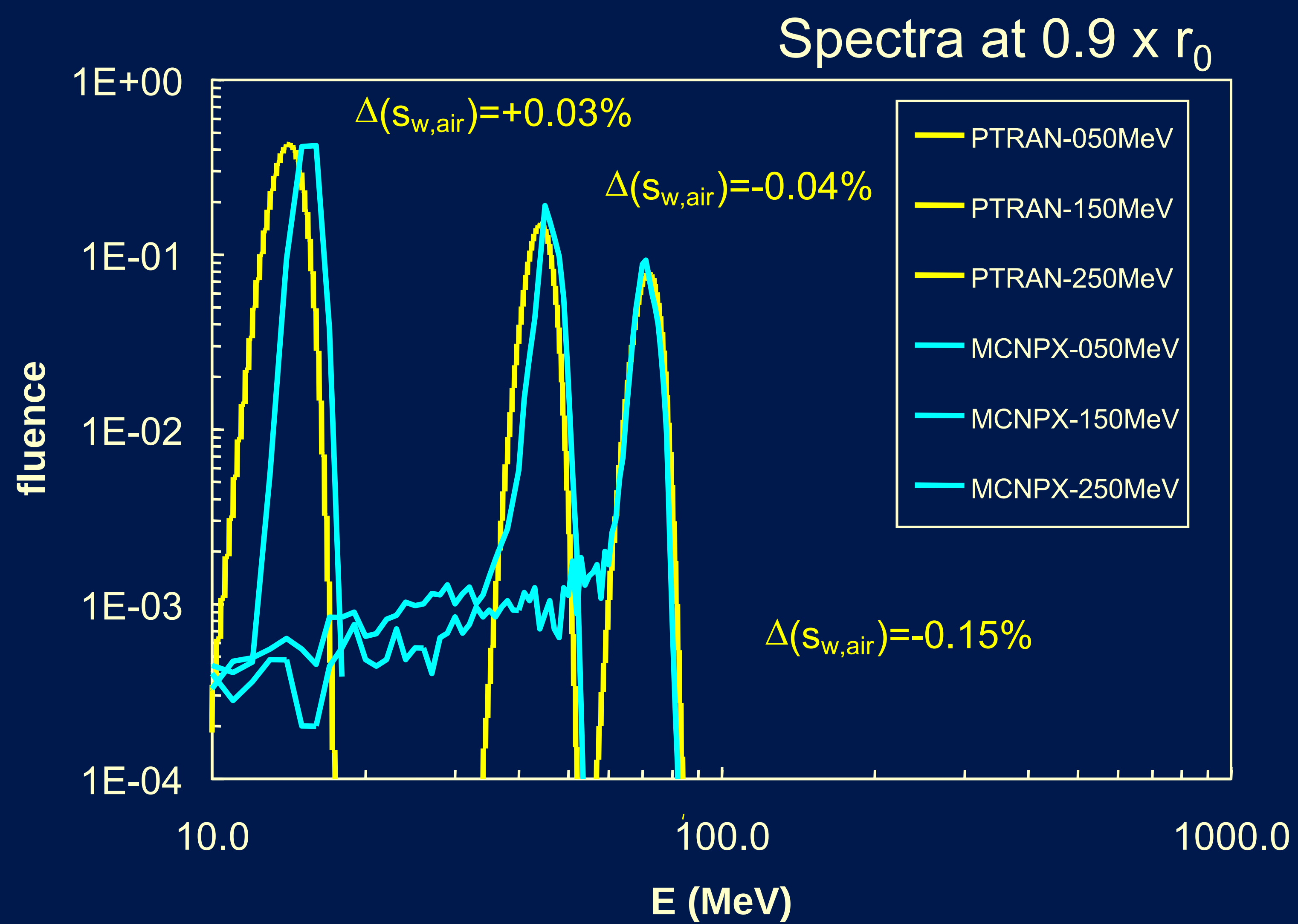
Example: 60 MeV pdd



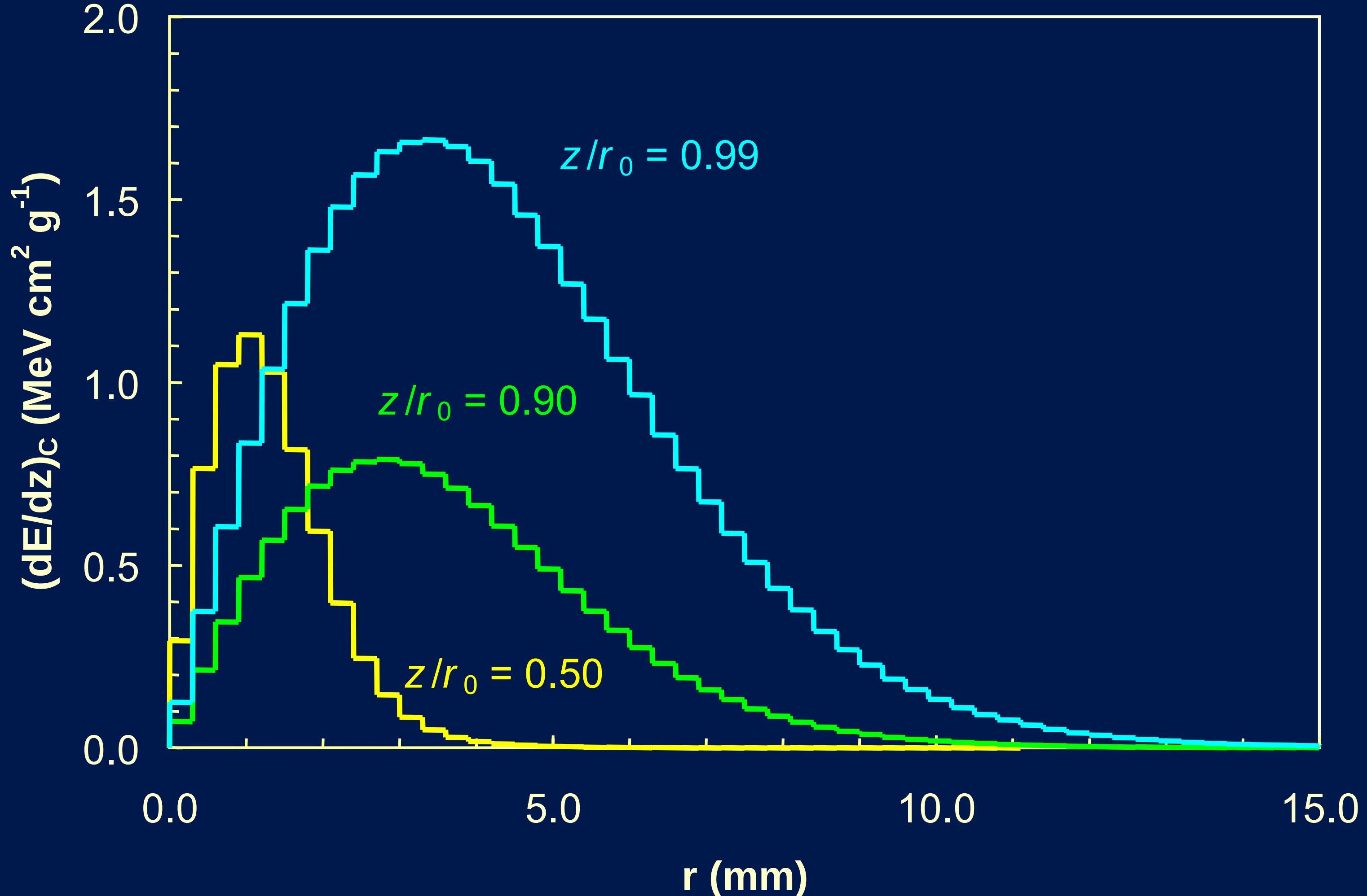
Example: 250 MeV pdd



Examples: proton spectra



Example: radial distributions (150 MeV)



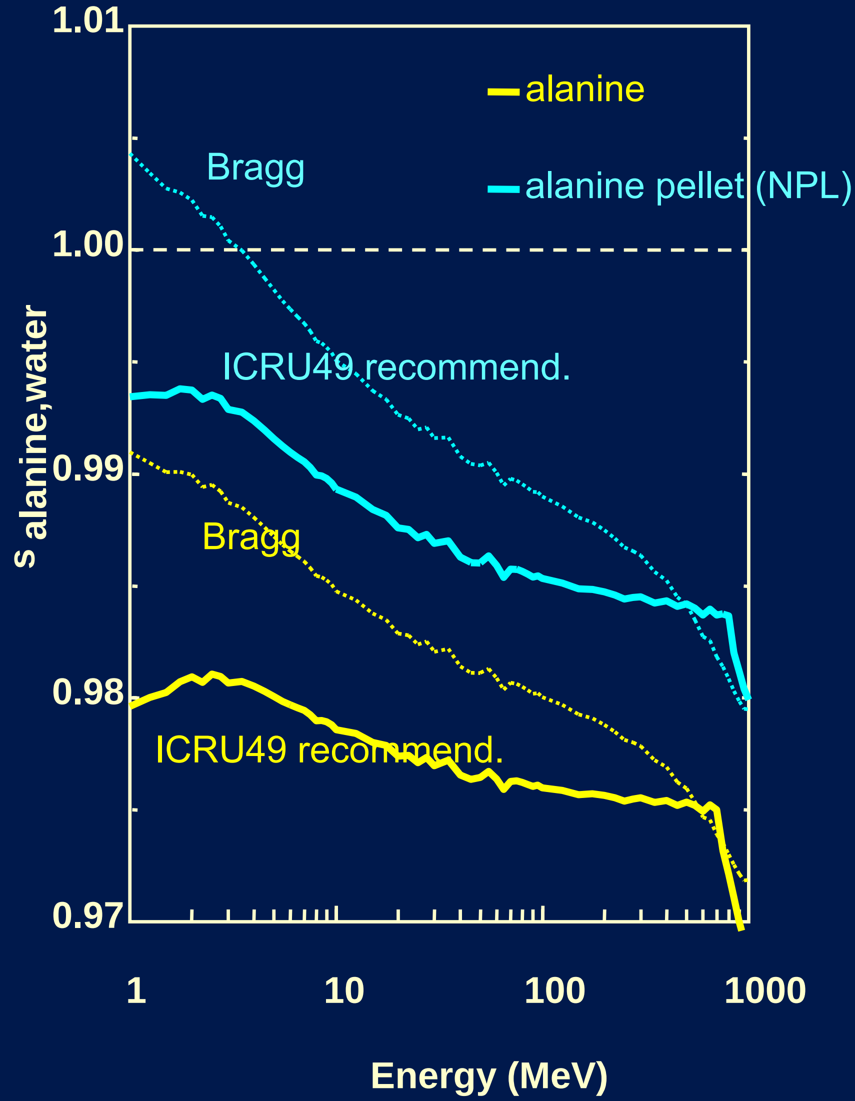
McPTRAN.MEDIA: aim

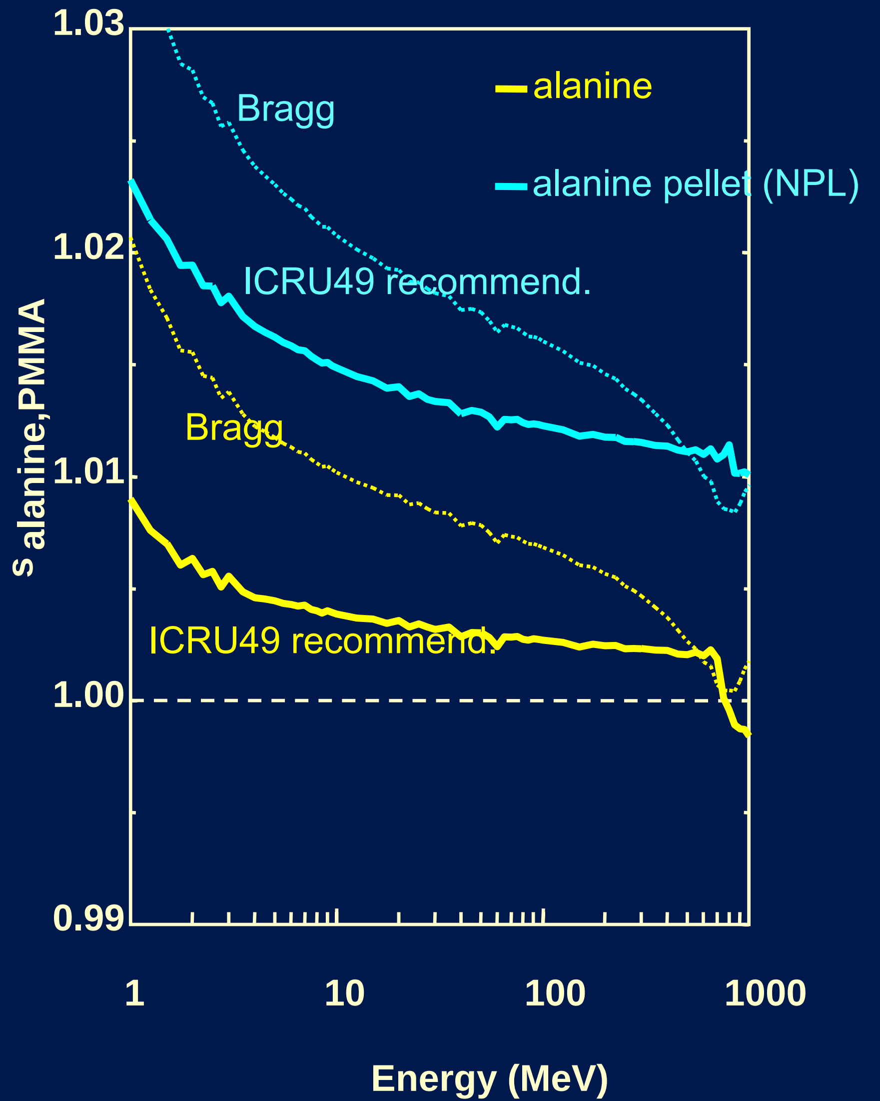
- Other materials than water
- Inhomogeneous slab geometries
- Broad rectangular and circular beams
- Incident beam with energy distribution
- Incident beam with angular distribution
- Implementation of modulator wheel

McPTRAN.MEDIA: data

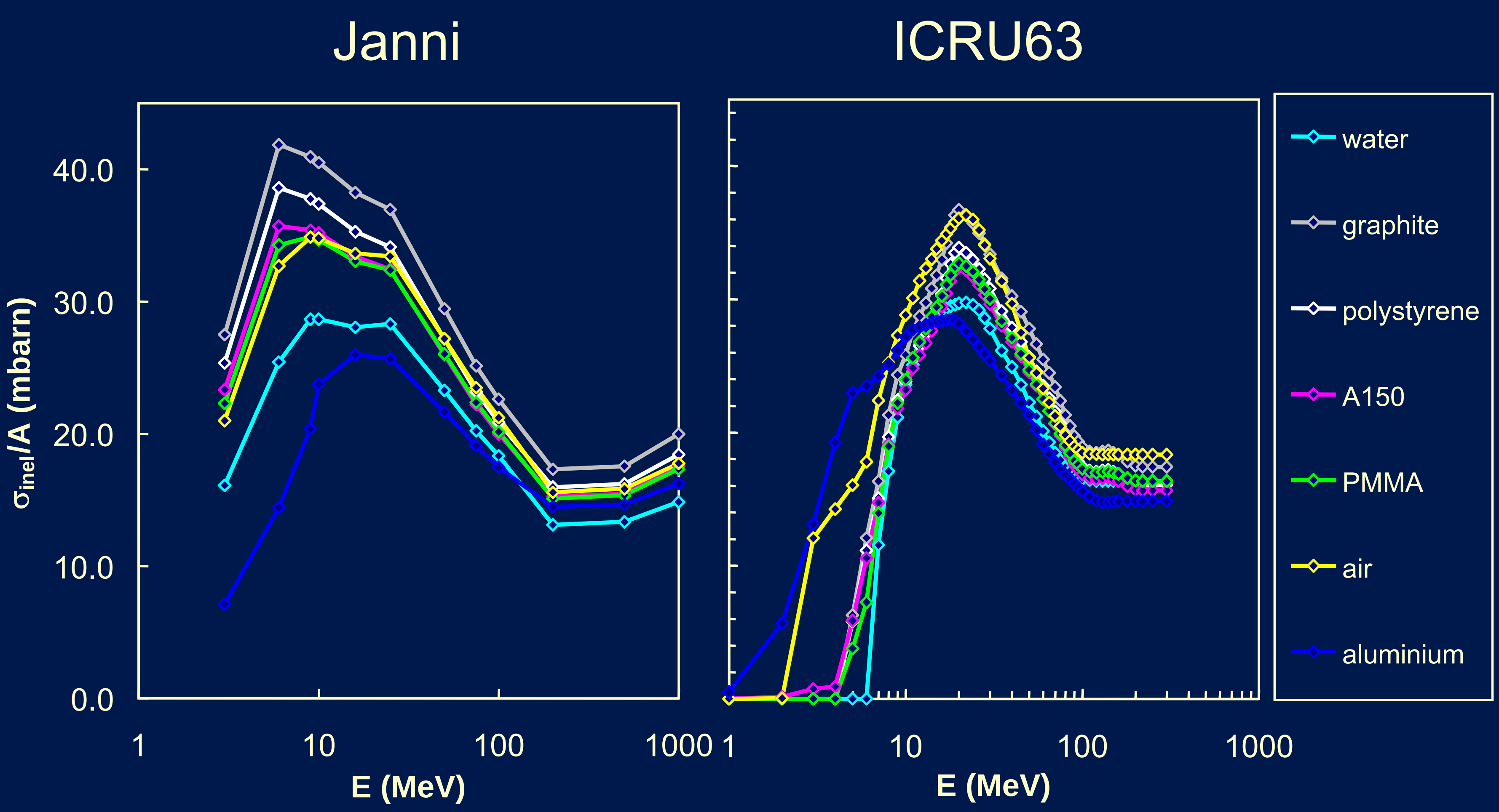
- Stopping powers: ICRU 49 (for materials not listed: Bragg + I_0 + Barkas)
- For Vavilov: S_1 and I_1 (from Inokuti et al. 1978, 1981 Phys. Rev. A 17:1229-1231 and 23:95-109)
- For Molière: k_{HF} (from Berger and Wang 1988 ed. Jenkins…)
- Inelastic nuclear cross sections: Janni (1982) and ICRU 63 (for materials not listed: interpolation as a function of A)

McPTRAN.MEDIA: Stopping powers
(consistent with ICRU 49)



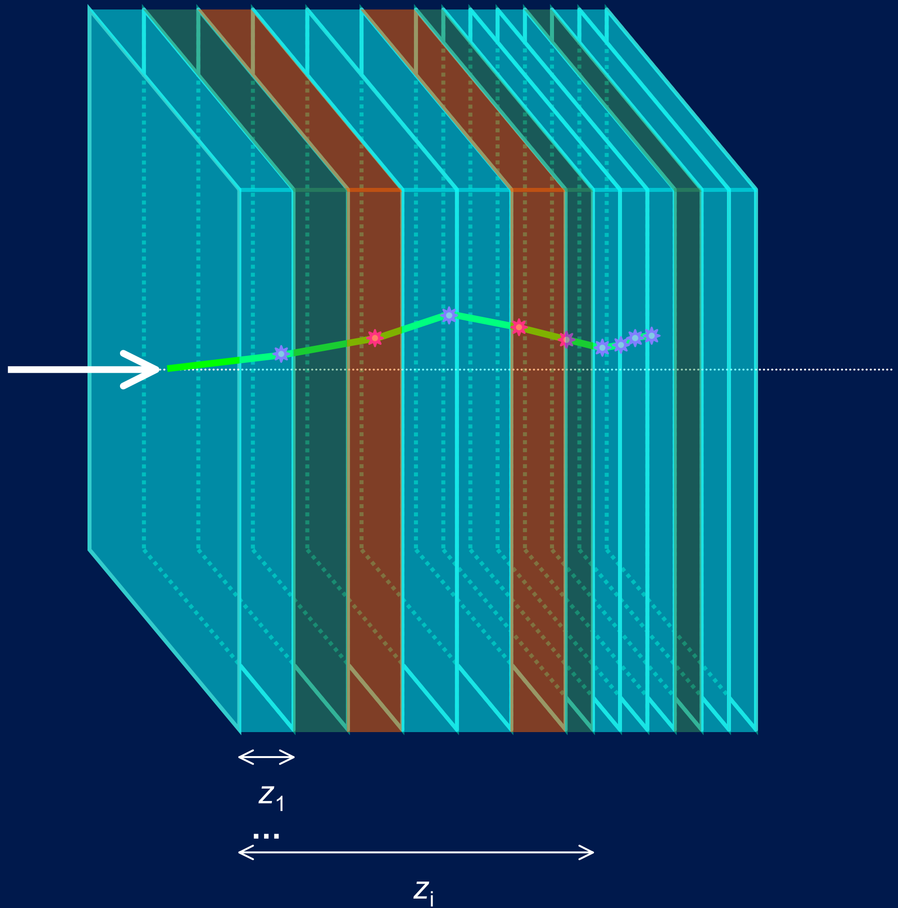


McPTRAN.MEDIA: Total inelastic nuclear cross sections

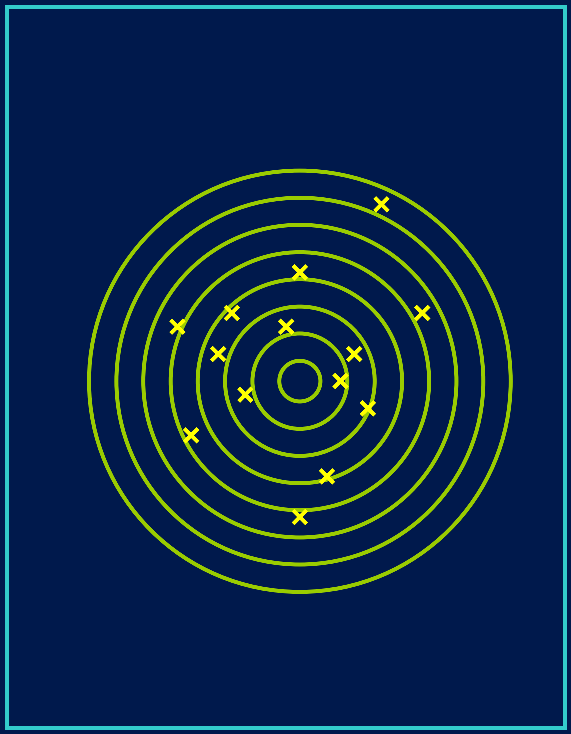


McPTRAN.MEDIA: geometry

transport



scoring



McPTRAN.MEDIA: boundary crossing

Linear interpolation of

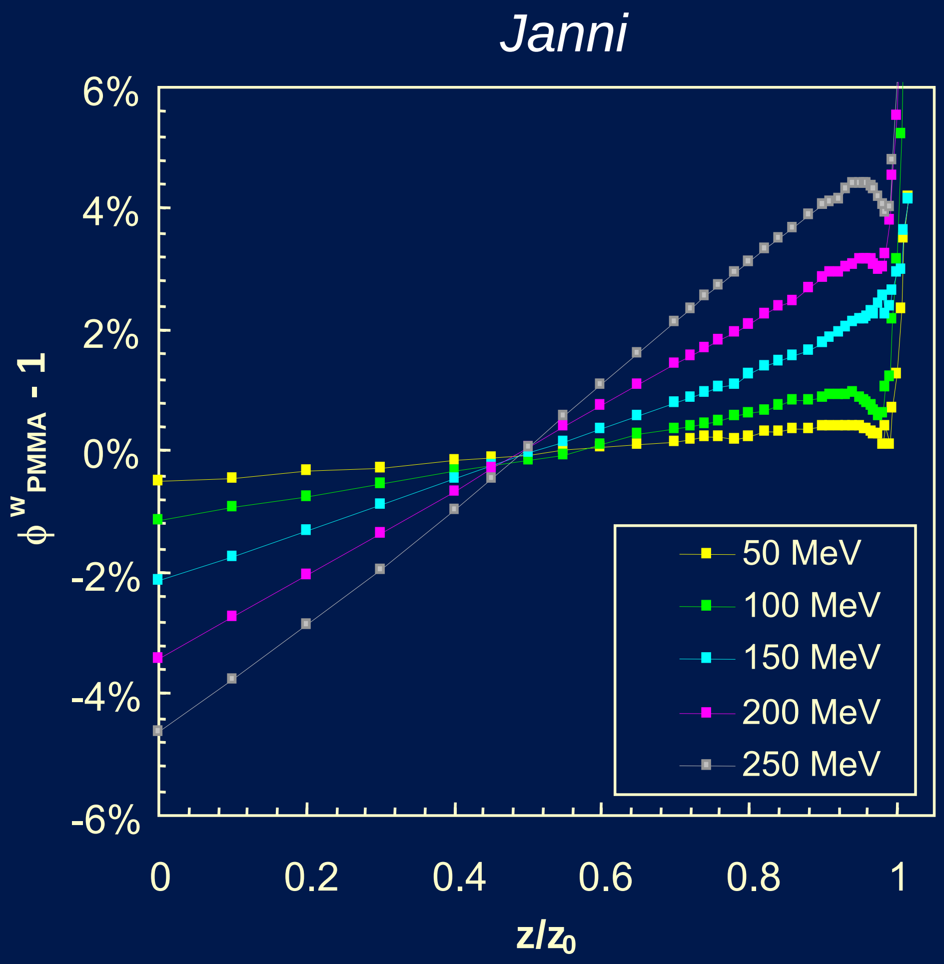
- Energy loss
- Angle
- Displacements Δx, Δy, Δz

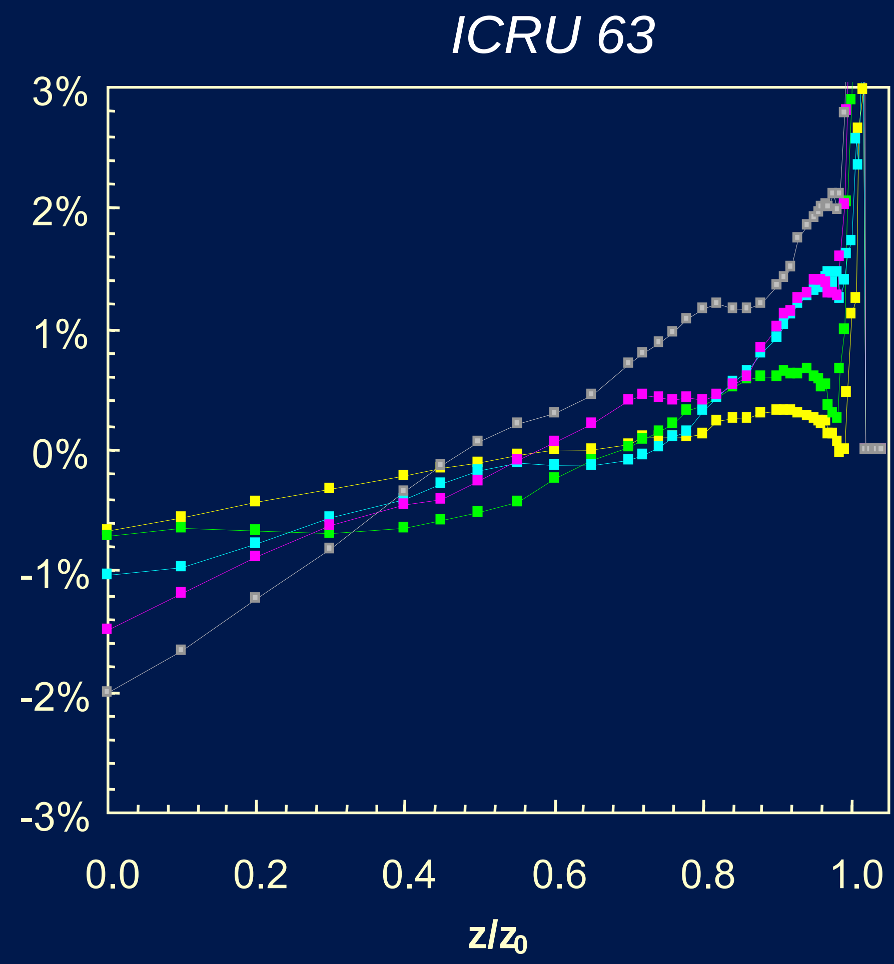
McPTRAN.MEDIA: example: fluence correction factors

$$D_w(z_w) = D_{pl}(z_{pl}).s_{w,pl}.\phi_{pl}^{w}$$

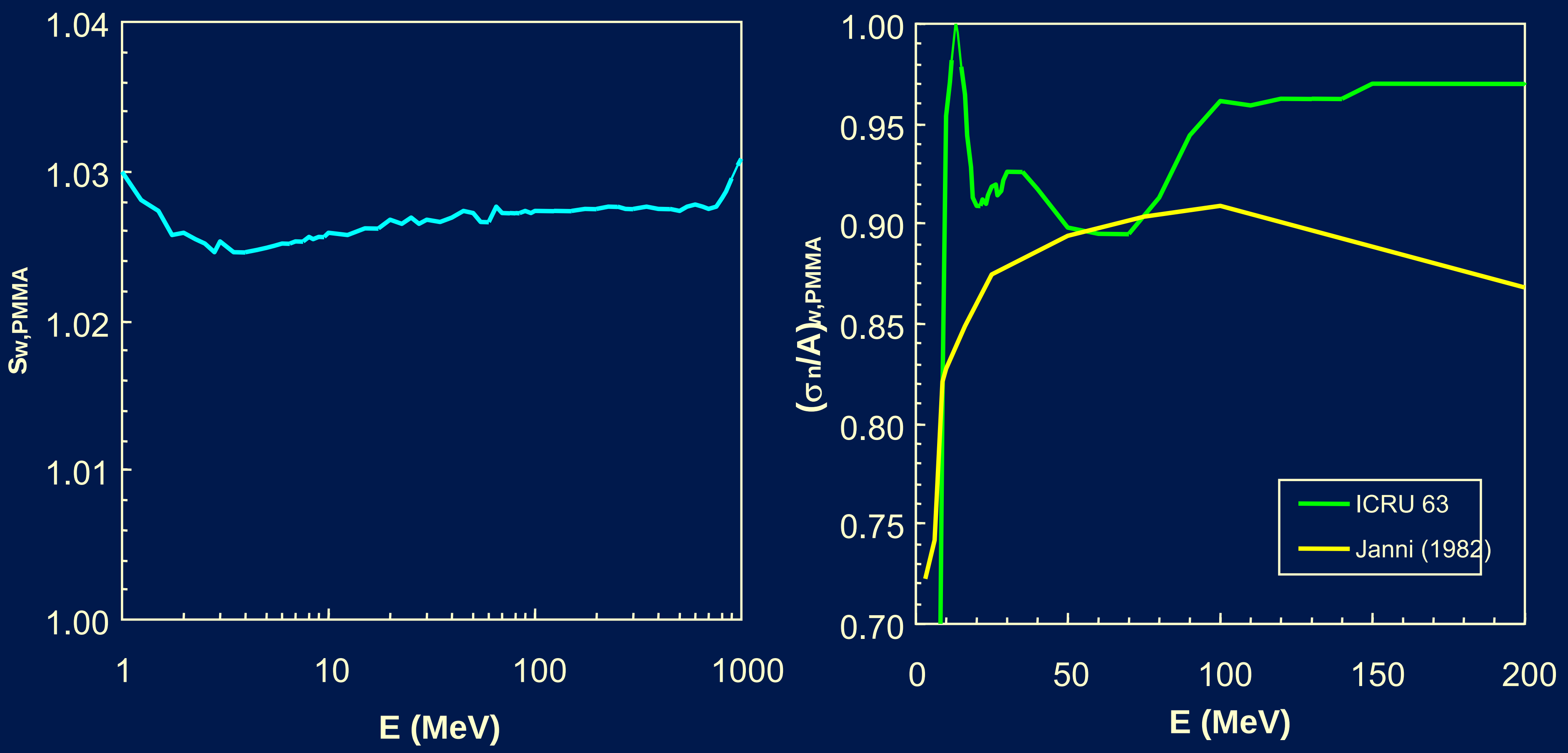
$$z_w = z_{pl} \cdot \frac{(z_0)_w}{(z_0)_{pl}}$$

McPTRAN.MEDIA: example: fluence correction factors

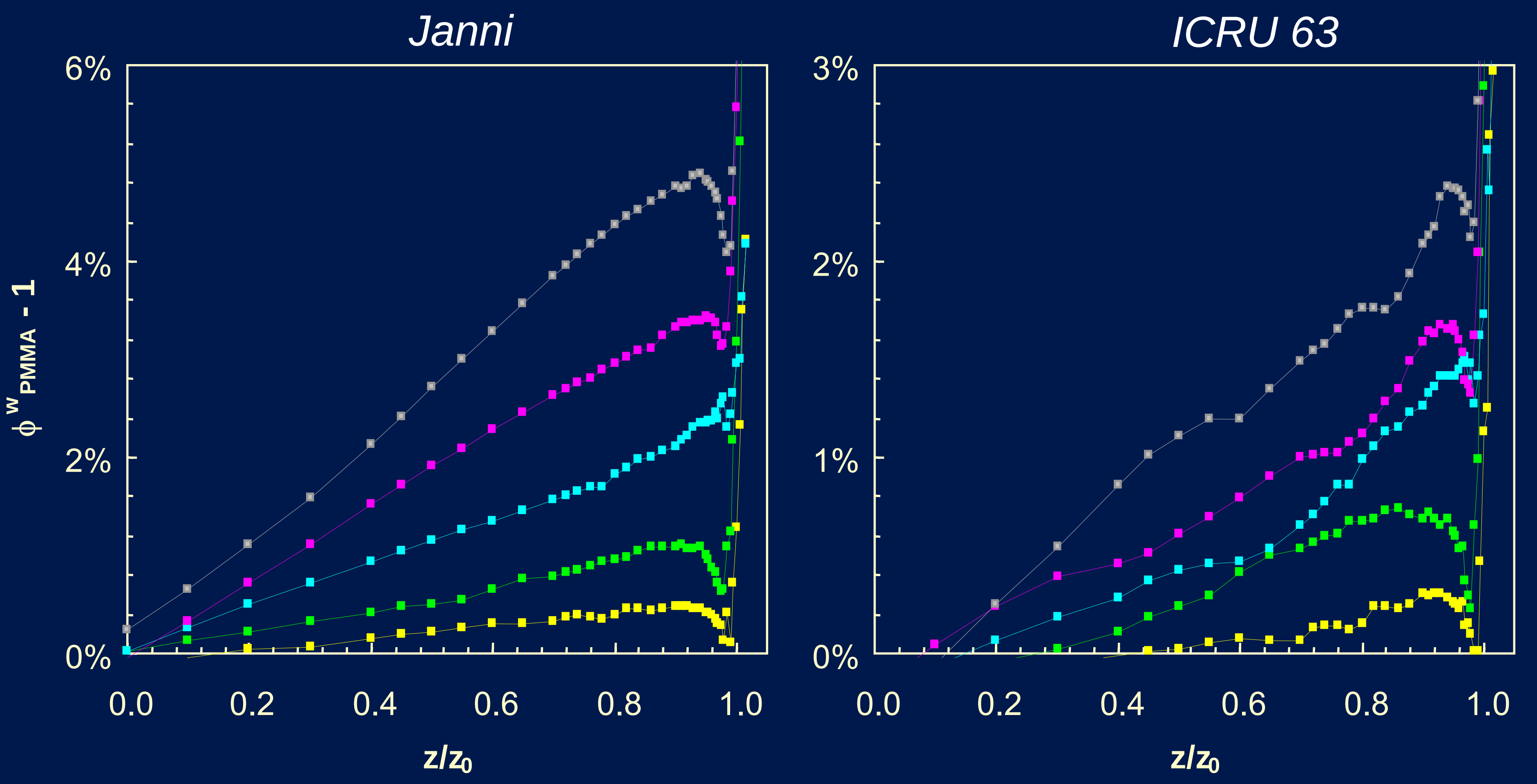




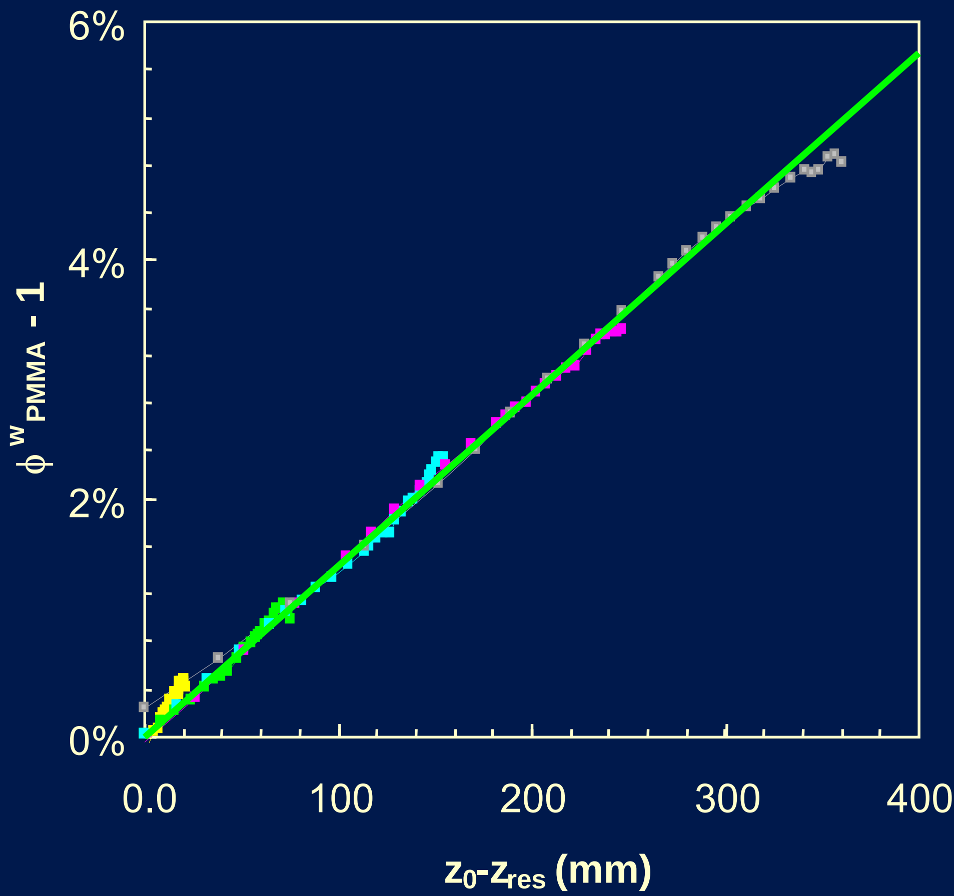
McPTRAN.MEDIA: example: fluence correction factors

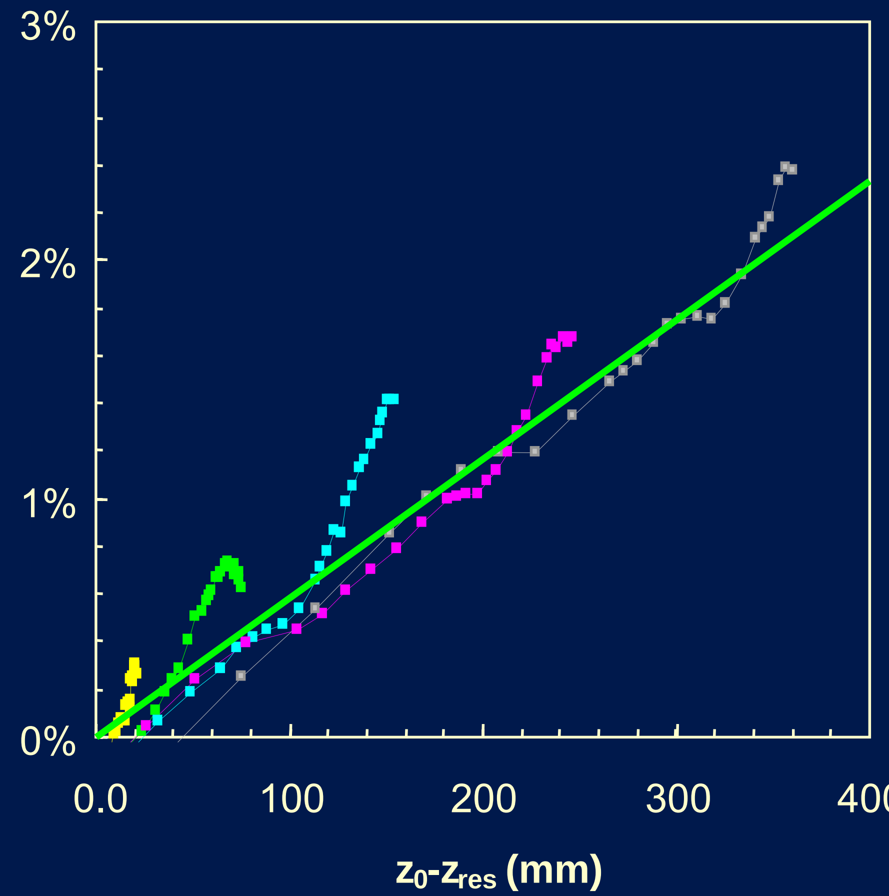


McPTRAN.MEDIA: example: fluence correction factors – correct conversion



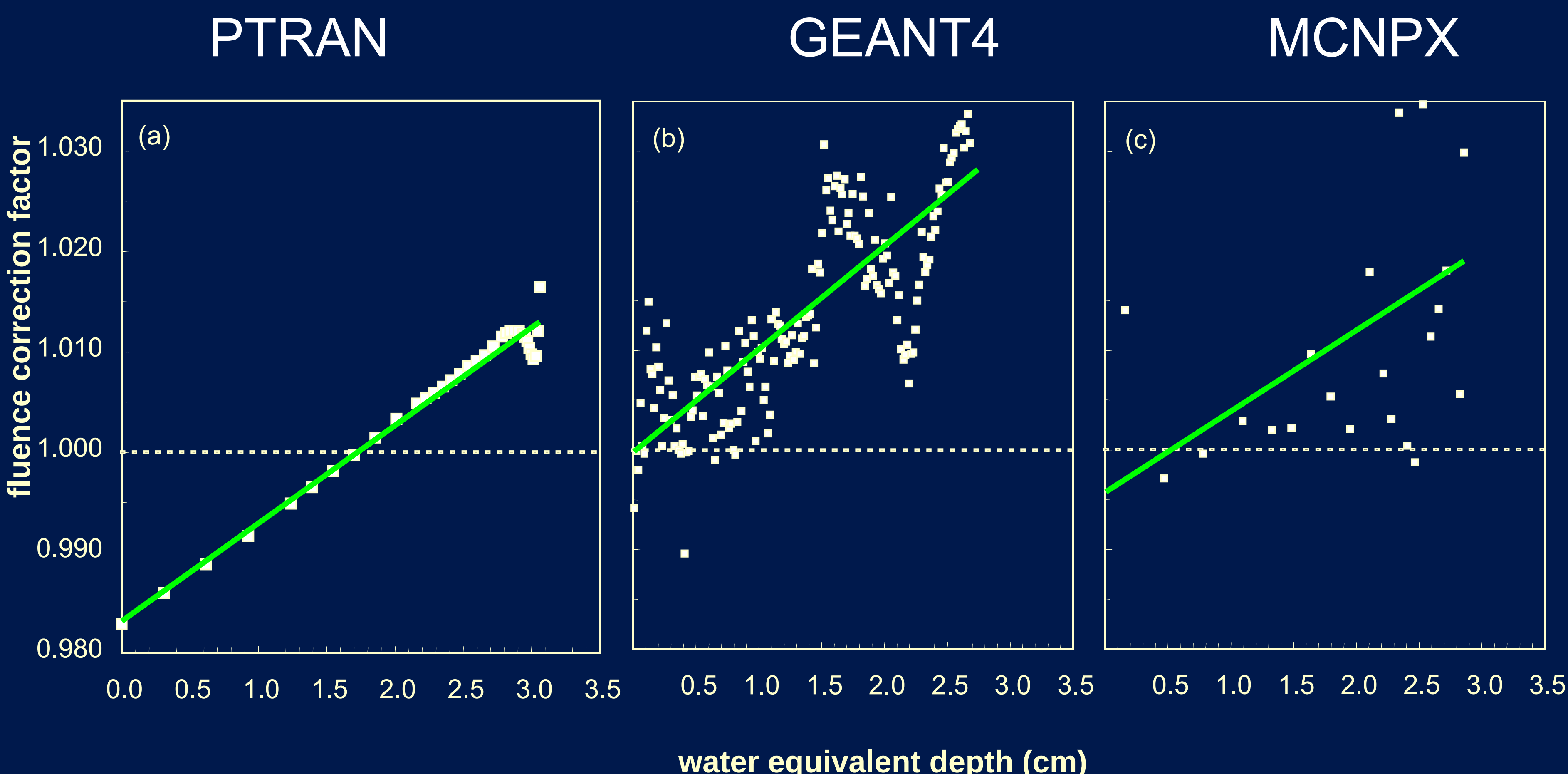
McPTRAN.MEDIA: example: fluence correction factors



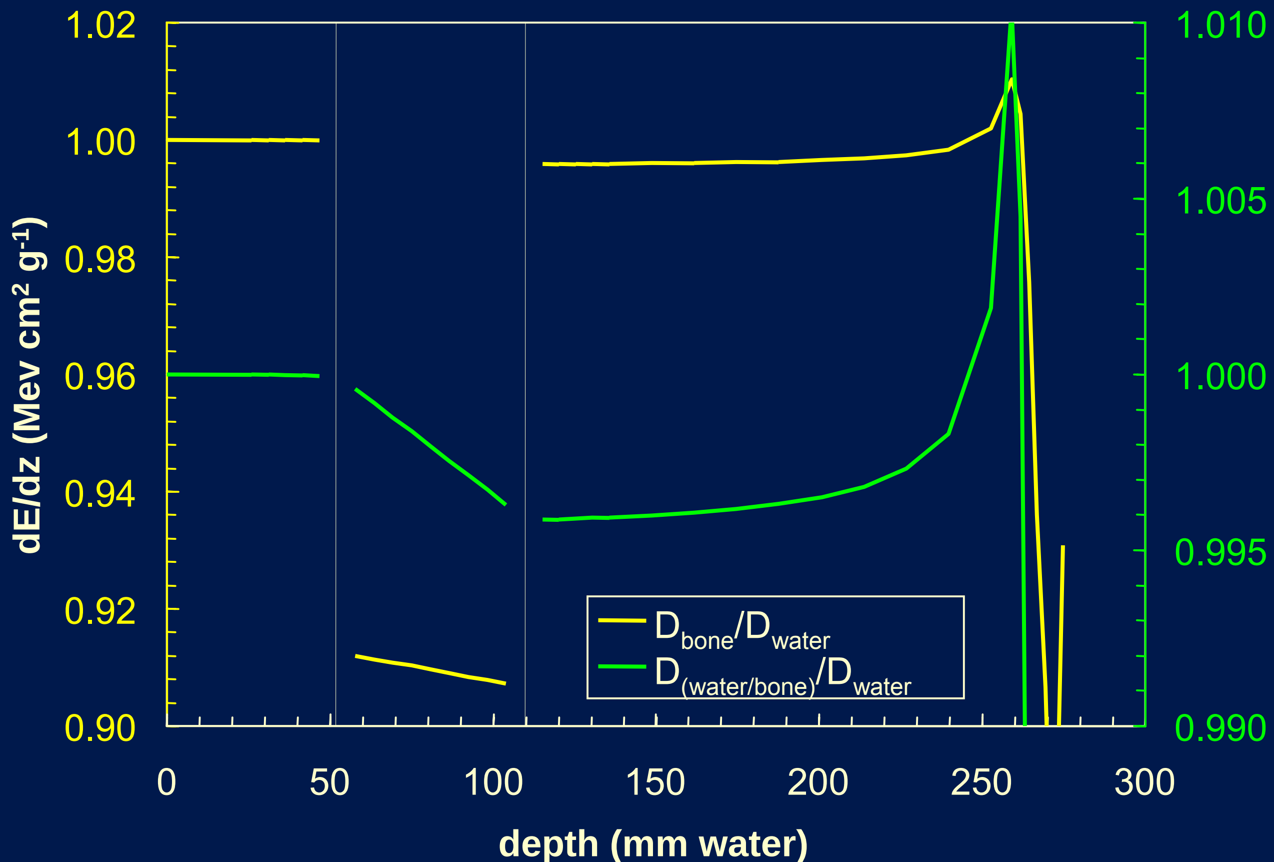


$$D_w(z_w) = D_{pl}(z_{pl}) \cdot \left[(S/\rho) + E(\sigma/A)\right]_{w,pl} \cdot e^{-N_A \cdot \int_T^{T_0} \left[\frac{1}{S_w(T')} \cdot \left(\frac{\sigma}{A}\right)_w - \frac{1}{S_{pl}(T')} \cdot \left(\frac{\sigma}{A}\right)_{pl} \right] dT'}$$

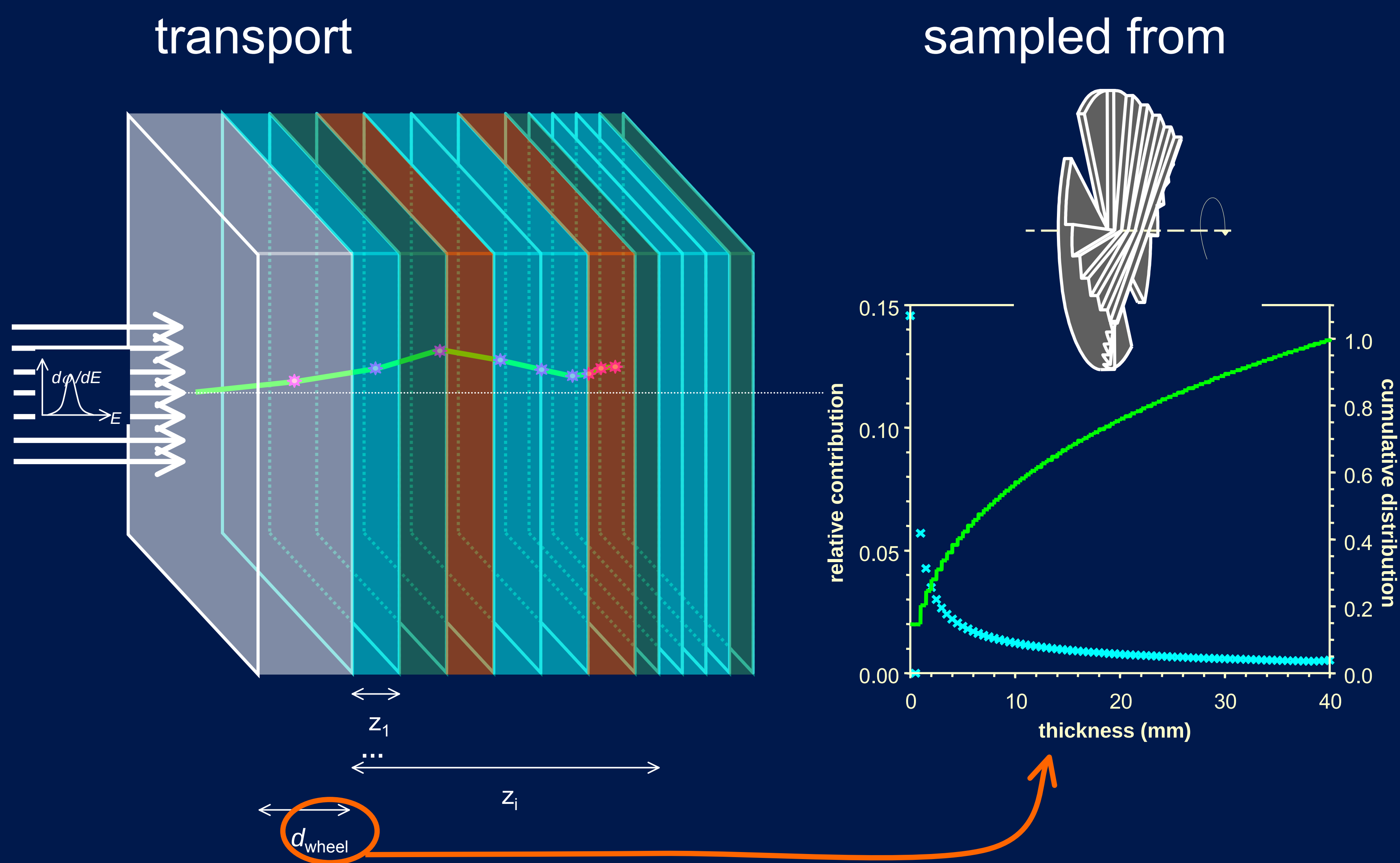
McPTRAN.MEDIA versus McNP and Geant: fluence correction factors



McPTRAN.MEDIA: example: bone slab in water



McPTRAN.MEDIA: modulator wheel



Interlude: Modulator wheel in GEANT4

(Paganetti 2004 Phys. Med. Biol. 49:N75-N82)

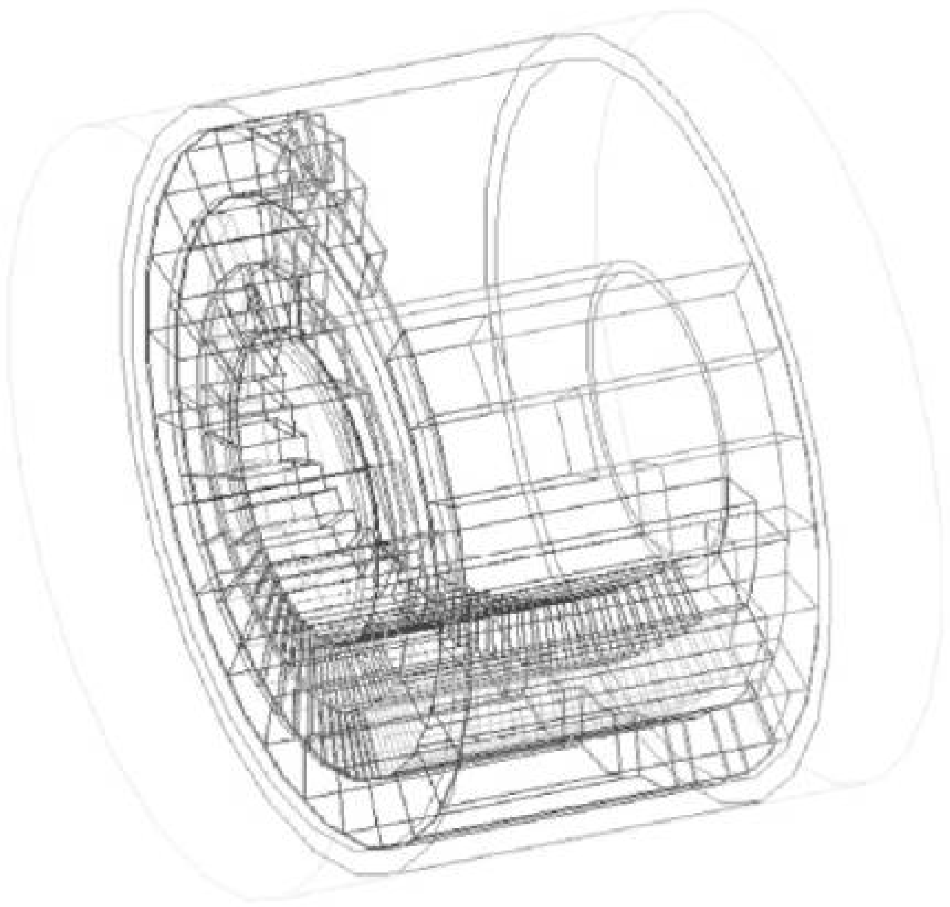
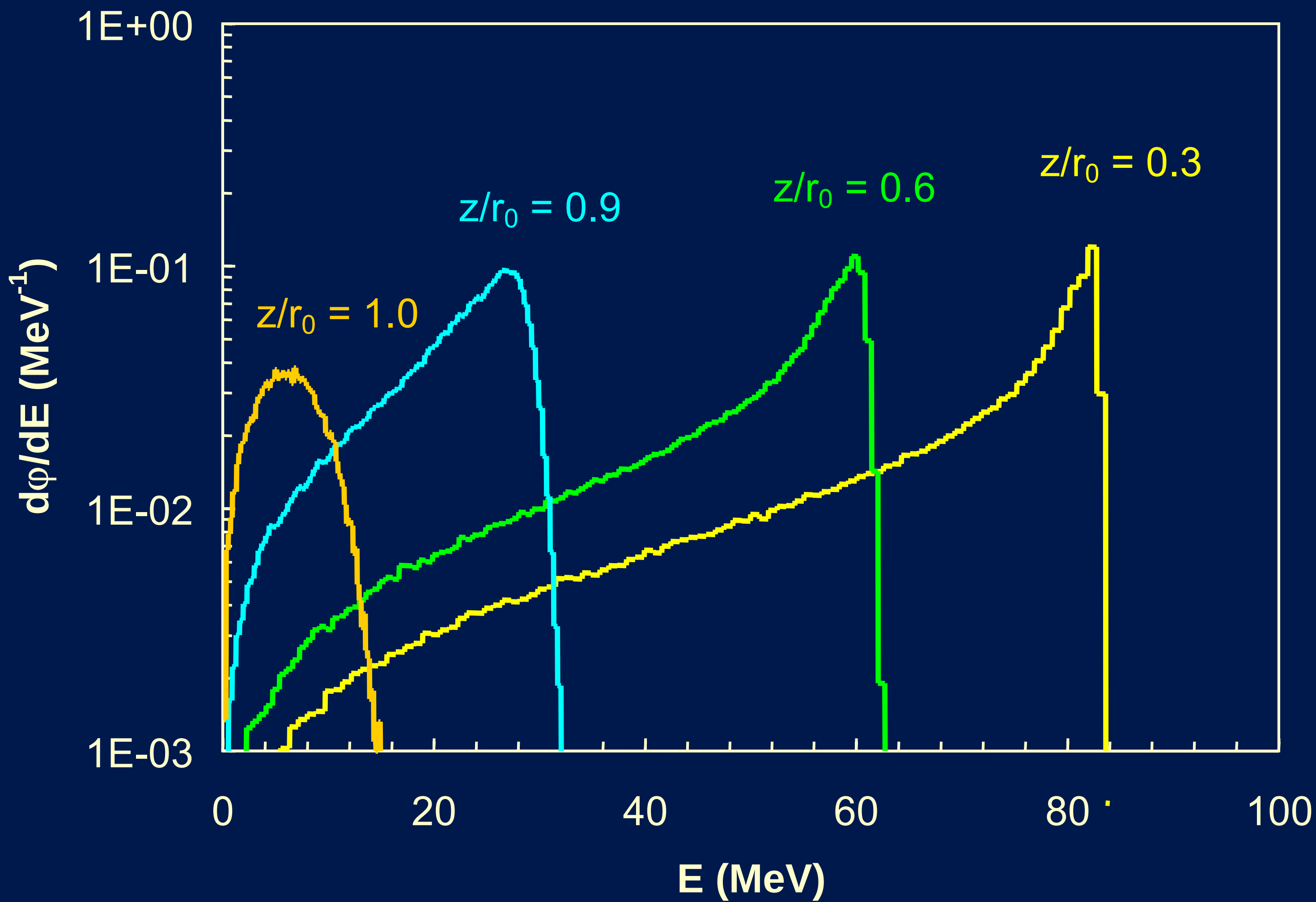
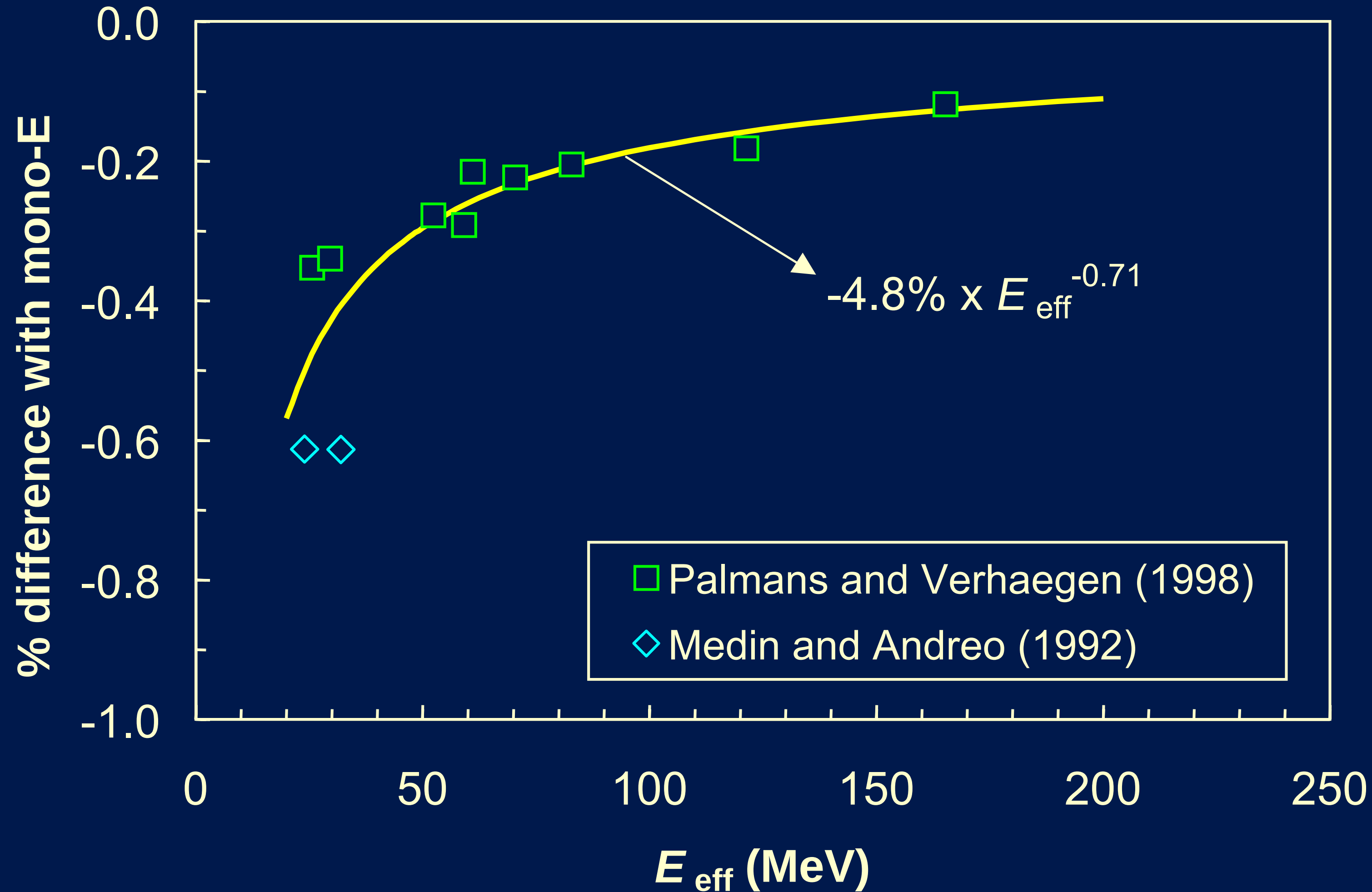


Figure 1. One of the range modulator wheels, consisting of three tracks, as modelled within GEANT4. The outer track is used for wobbling while the two inner tracks are for broad beam modulation. The beam would be entering from the right. Light grey segments refer to low-*Z* materials, dark grey segments refer to high-*Z* materials.

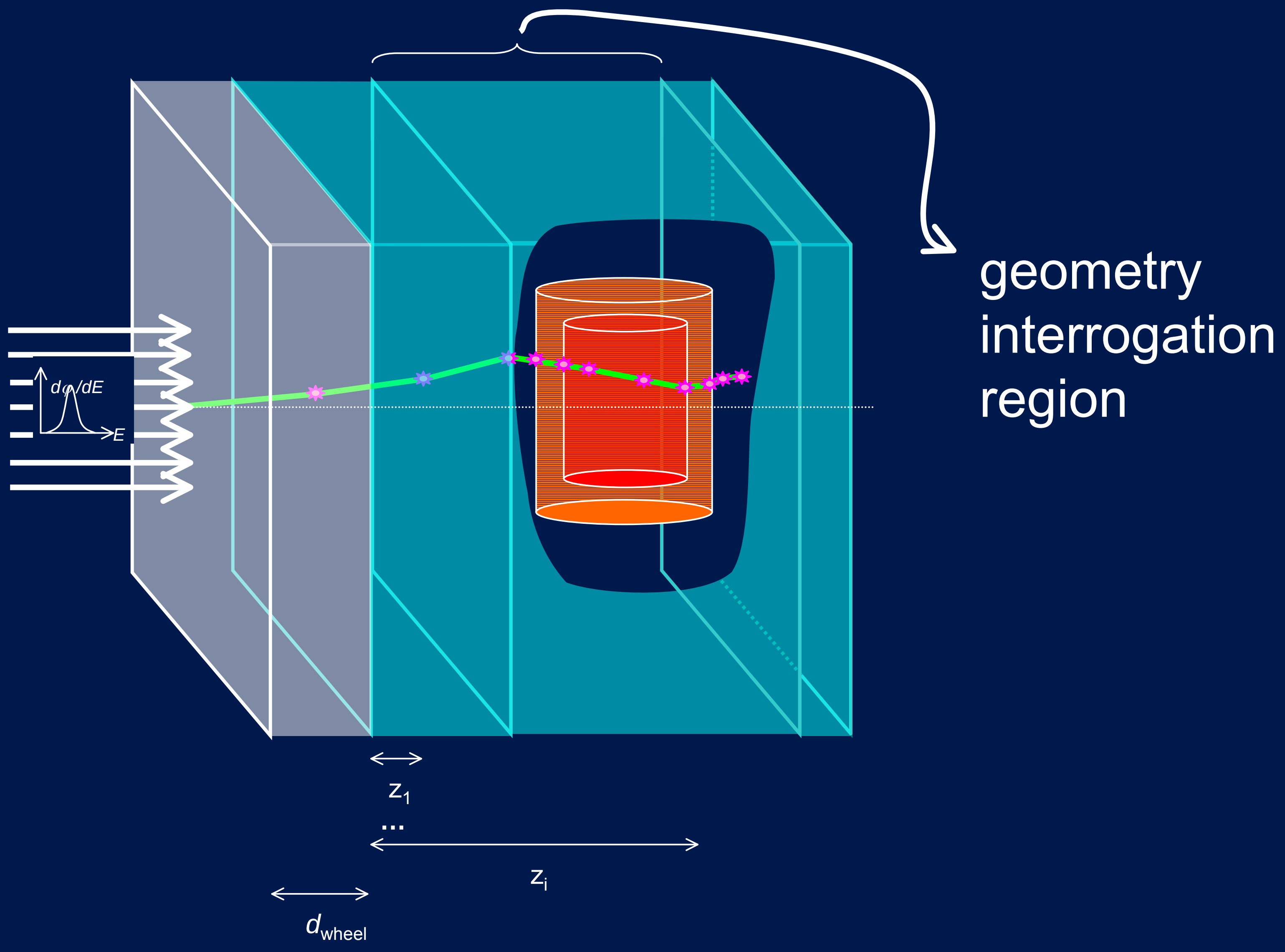
McPTRAN.MEDIA + modwheel: example: spectra in modulated proton beam



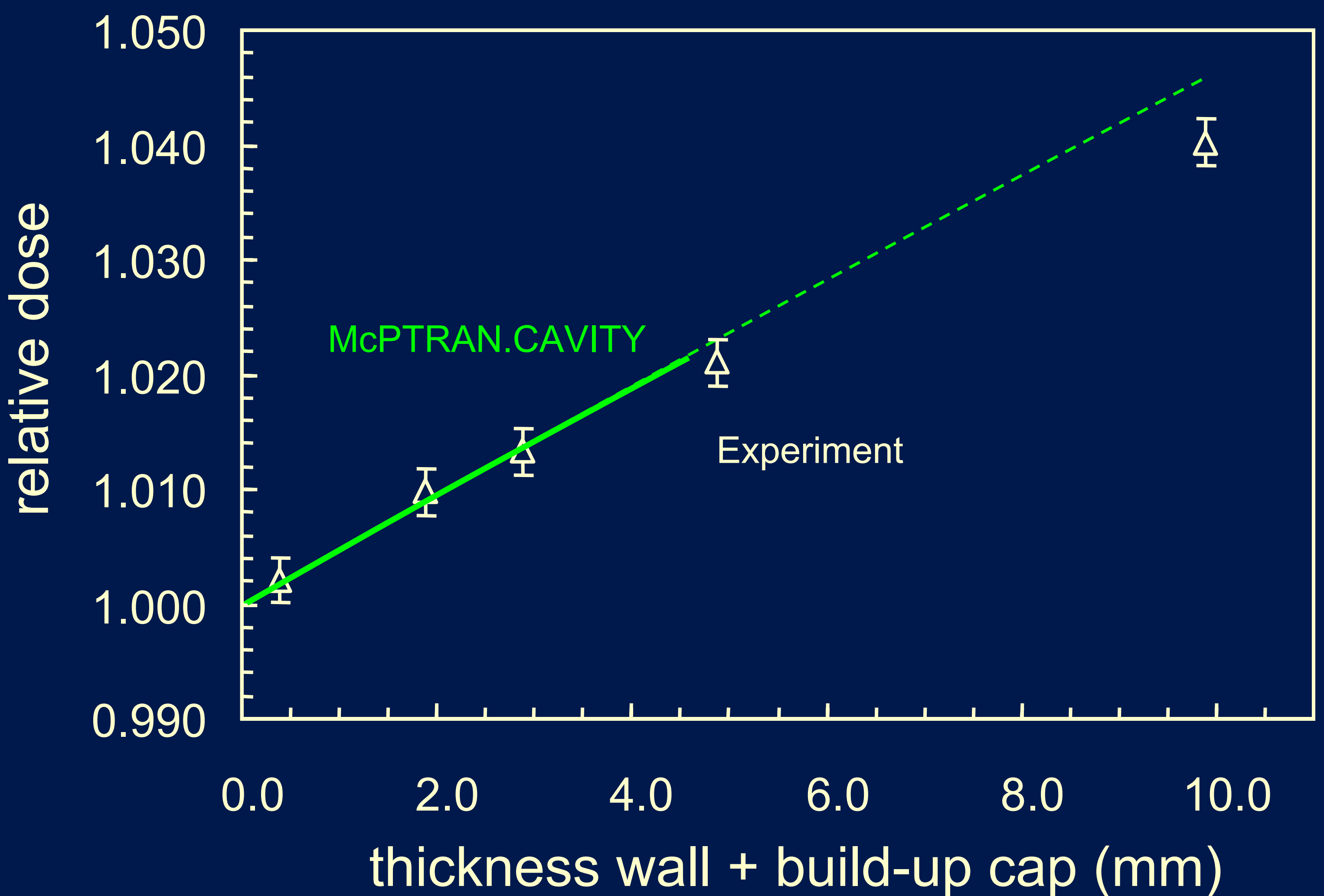
McPTRAN.MEDIA: example: stopping power ratios in modulated proton beam



McPTRAN.CAVITY: geometry & scoring

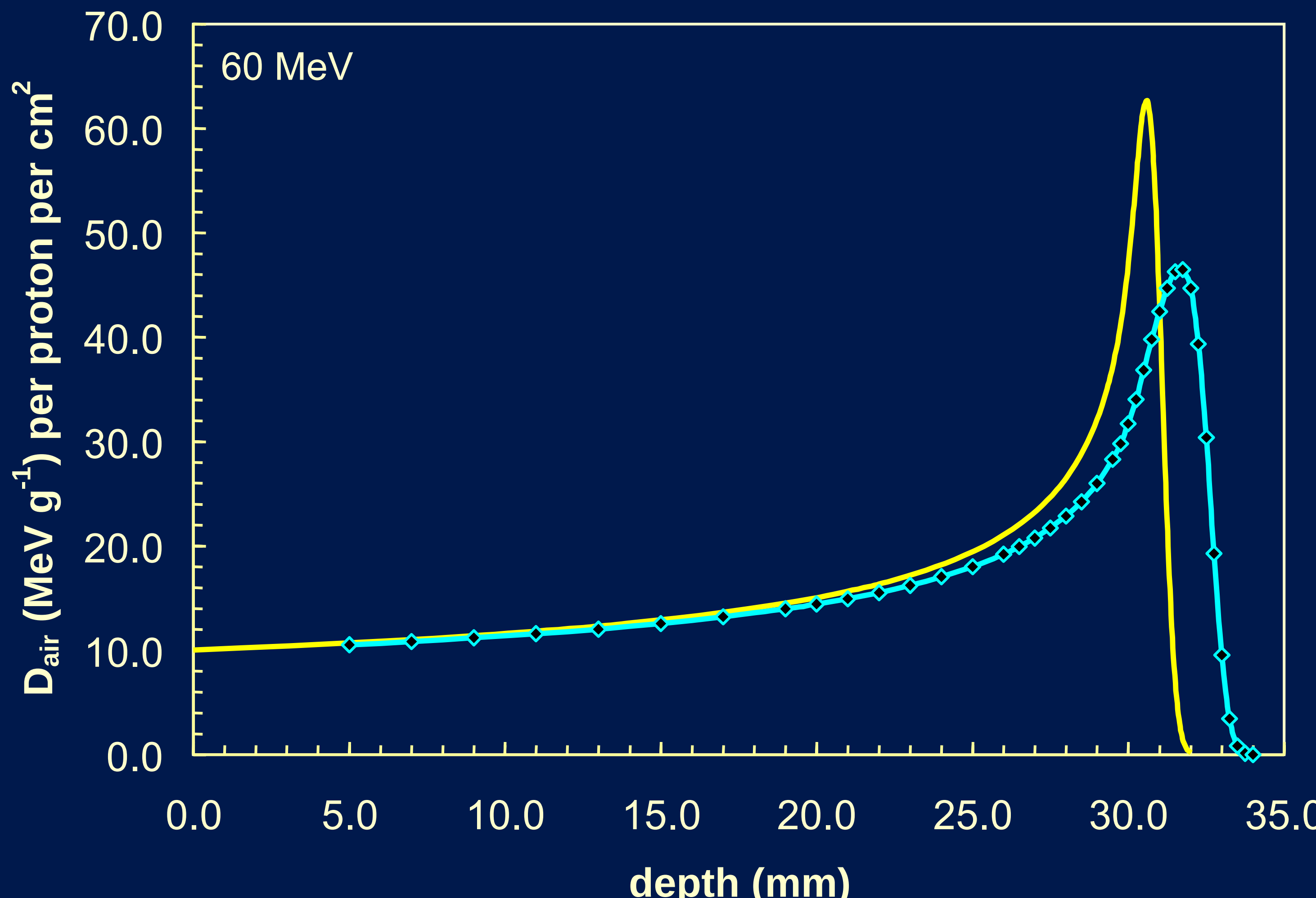


McPTRAN.CAVITY: example: $p_{wall,gr}$



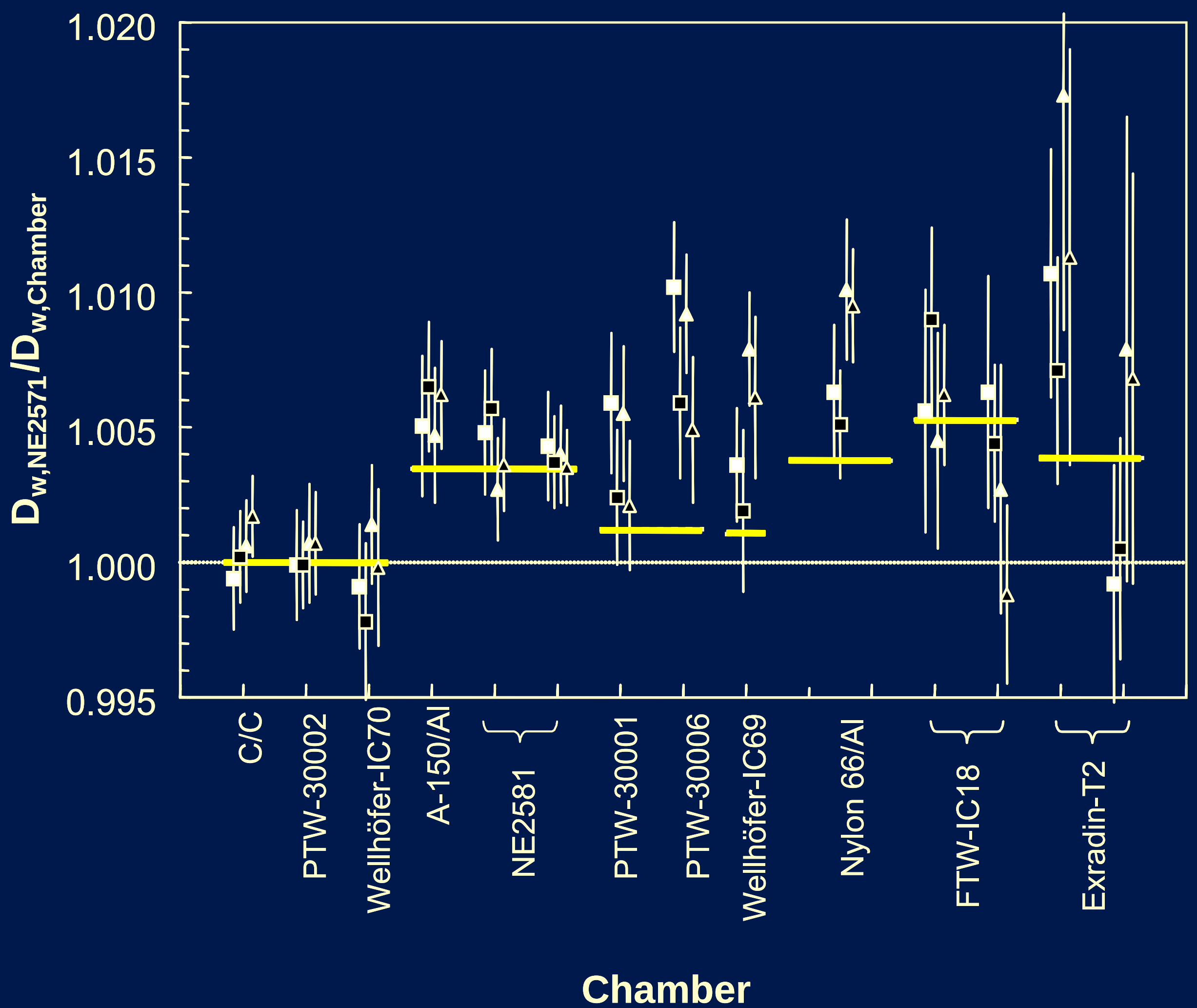
McPTRAN.CAVITY: example: gradient corrections for thimble IC

(see grid calculation demo)

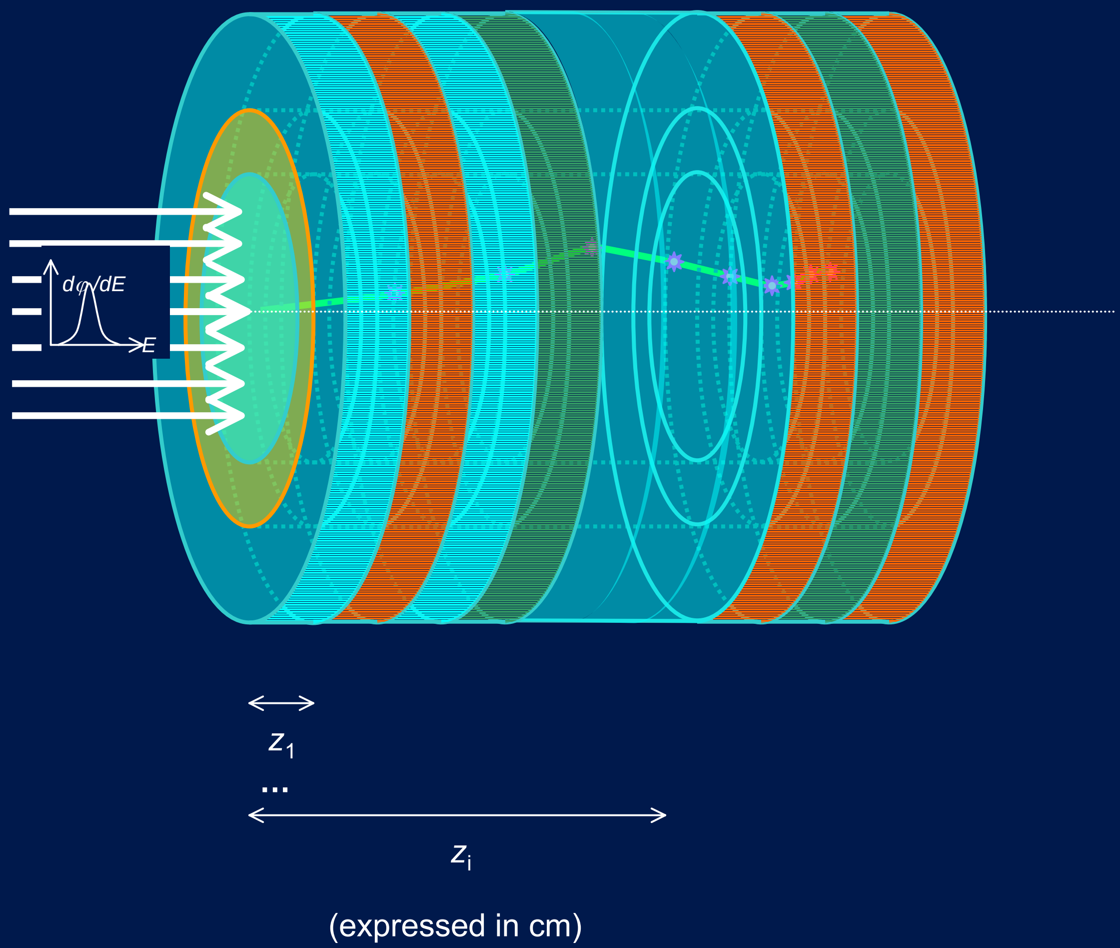


McPTRAN.CAVITY: example: secondary electron perturbation

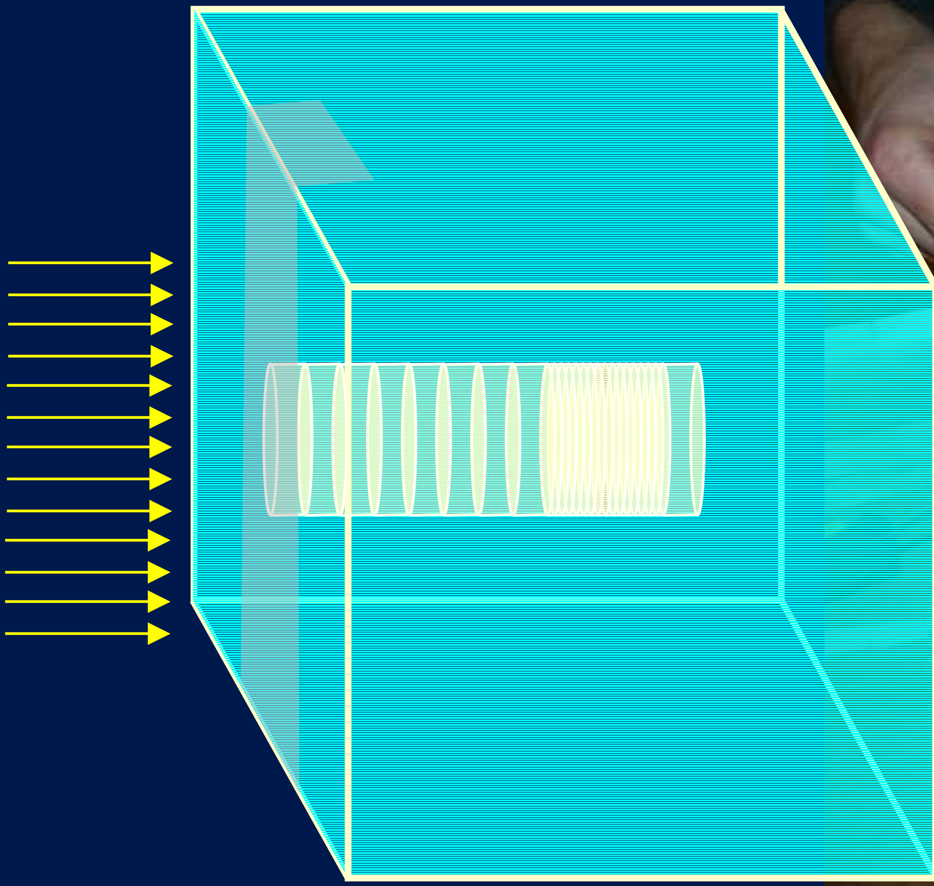
(Verhaegen and Palmans, Med. Phys. 28:2088-2095)

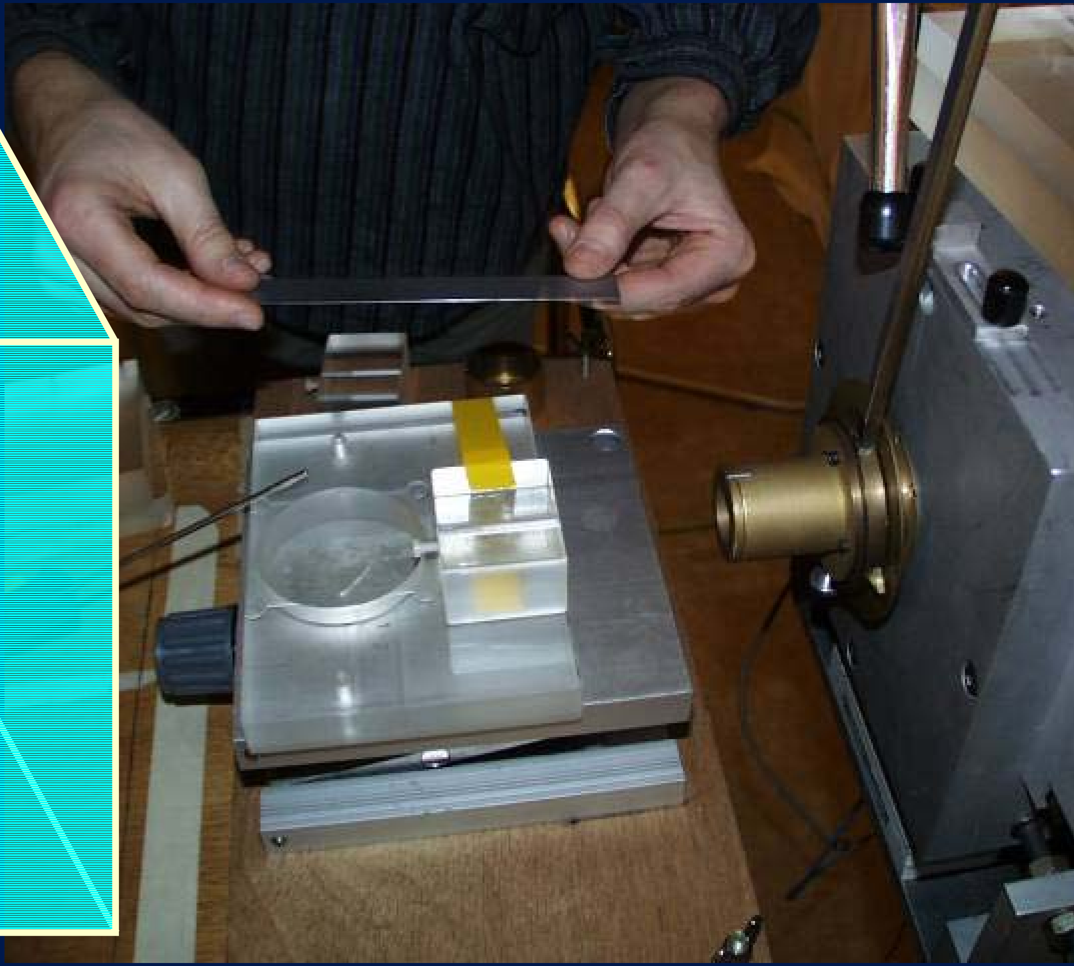


McPTRAN.RZ

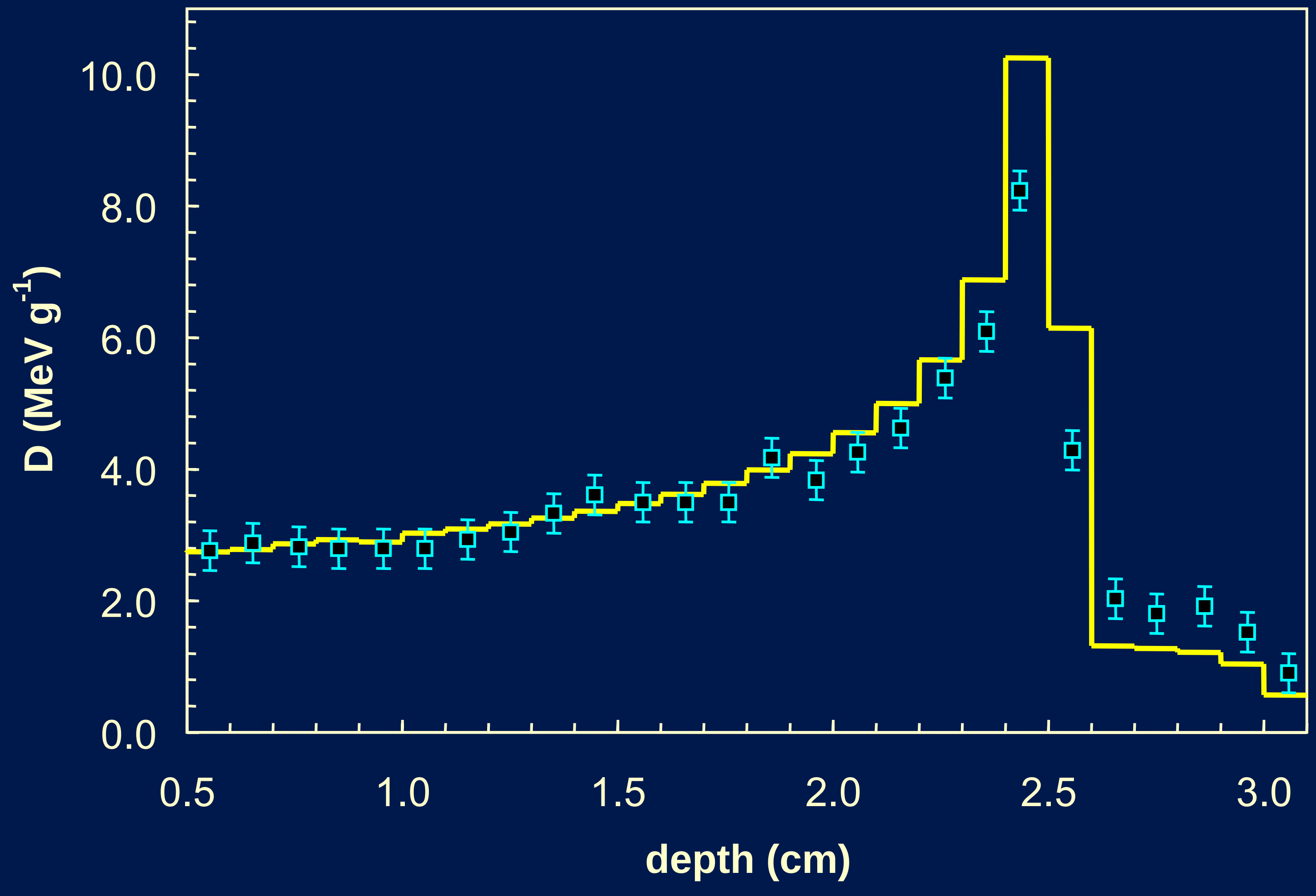


McPTRAN.RZ: example: Alanine stack in PMMA





McPTRAN.RZ: example: Alanine stack in PMMA



That's all folks…

Thanks!