



## Linear Collider Collaboration Tech Notes

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### Energy Deposition Using EGS4

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**Abstract:** Quick note on how to run EGS4 to calculate the energy deposition in a material due to irradiation from choice of electrons, positrons, or photons. Presently have two EGS4 user codes set up to calculate energy deposition. The first was set up by Ralph Nelson for my initial exposure to EGS4. This code assumes an incident monoenergetic pencil (i.e. no transverse size) beam of electrons, photons, or positrons ( $I_{Qin} = -1, 0, 1$  respectively). Initial beam energy ( $E_{KEin}$ ) and number of incident particles ( $N_{cases}$ ) are specified by the user. The target geometry consists of (in this case) 10 concentric cylinders that have been cut longitudinally into 8 slices. A second user code looks for a user specified incident, gaussian rms beam size ( $SIGX$  and  $SIGY$  in cm) and  $E_{KEin}$  is now the first harmonic, energy cutoff ( $E_{c10}$ ) in MeV for a  $K_u=1$  undulator spectrum. EGS4 uses  $SIGX/Y$  and  $E_{c10}$  to generate the initial beam position and incident energy of the individual photons. In addition, the user must provide a pair of data input files to define the cumulative undulator photon spectrum. The target geometry is the same as in the monoenergetic photon case. By way of example, these codes are used to model the energy deposition in 0.4 r.l. Ti due to photons produced by the Tesla TRD undulator driven by the 250 GeV Tesla primary electron beam.

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rev 5: 4/30/02

### Abstract

Quick note on how to run EGS4 to calculate the energy deposition in a material due to irradiation from choice of electrons, positrons, or photons. Presently have two EGS4 user codes set up to calculate energy deposition. The first was set up by Ralph Nelson for my initial exposure to EGS4. This code assumes an incident monoenergetic pencil (i.e. no transverse size) beam of electrons, photons, or positrons ( $I_{Qin} = -1,0,1$  respectively). Initial beam energy ( $E_{KEin}$ ) and number of incident particles ( $N_{cases}$ ) are specified by the user. The target geometry consists of (in this case) 10 concentric cylinders that have been cut longitudinally into 8 slices. A second user code looks for a user specified incident, gaussian rms beam size ( $SIGX$  and  $SIGY$  in cm) and  $E_{KEin}$  is now the first harmonic, energy cutoff ( $E_{c10}$ ) in MeV for a  $K_u=1$  undulator spectrum. EGS4 uses  $SIGX/Y$  and  $E_{c10}$  to generate the initial beam position and incident energy of the individual photons. In addition, the user must provide a pair of data input files to define the cumulative undulator photon spectrum. The target geometry is the same as in the monoenergetic photon case. By way of example, these codes are used to model the energy deposition in 0.4 r.l. Ti due to photons produced by the Tesla TRD undulator driven by the 250 GeV Tesla primary electron beam.

Presently have two EGS4 user codes set up to calculate energy deposition. The first is: `/u/ad/jcs/egsrns/ucRTC_temp/ucRTZ_temp.mortran` . The data input template is: `/u/ad/jcs/egsrns/ucRTC_temp/ucRTZ_temp.data` . These were both set up by Ralph Nelson for my initial exposure to EGS4. This code assumes an incident monoenergetic pencil (i.e. no transverse size) beam of either electrons, photons, or positrons ( $I_{Qin} = -1,0,1$  respectively). Initial beam energy ( $E_{KEin}$ ) and number of incident particles ( $N_{cases}$ ) are specified by the user.

`/u/ad/jcs/egsrns/ucRTC_temp/ucRTZ_temp1.data` has been set up to model the energy deposition due to 100,000 photons of energy 22.2 MeV incident upon 0.4 radiation lengths of Ti. The target geometry is shown in figure 1. It consists of (in this case) of 10 concentric cylinders that have been sliced longitudinally into 8 slices. The results of running Xegs4run are written into `/u/ad/jcs/egsrns/ucRTC_temp/egs4job.out10`.

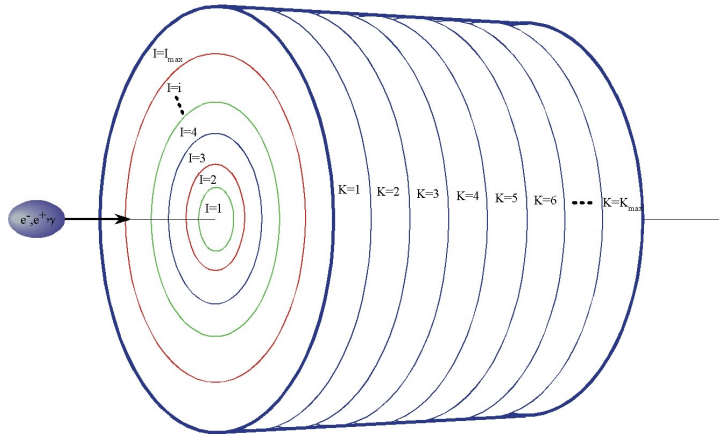


Figure 1.: Geometry used with EGS4 to calculate the energy deposition in a cylindrical target.

The second user code is

`/u/ad/jcs/egsrns/yieldcalc/phtnspctrm/ucRTZ_temp_spctry.mortran` . The data template for this is:

`/u/ad/jcs/egsrns/yieldcalc/phtnspctrm/ucRTZ_temp_spctry.data` . This code looks for a user specified incident, gaussian rms beam size (`SIGX` and `SIGY` in cm) and `EKEin` is now the first harmonic, energy cutoff ( $E_{c10}$ ) in MeV for a  $K_u=1$  undulator spectrum. EGS4 uses `SIGX/Y` and  $E_{c10}$  to generate the initial beam position and incident energy of the individual photons. The initial coordinates are written into:

`/u/ad/jcs/egsrns/yieldcalc/phtnspctrm/input_x_y_E.out`. And the results are written into `/u/ad/jcs/egsrns/yieldcalc/phtnspctrm/egs4job.out10`.

Figures 2a and 2b are the average of 7 `ucRTZ_temp_spctry` runs with 100,000 photons, `SIGX=SIGY=0.75` mm, and  $E_{c10}=28$  MeV ( $\langle E_{ph} \rangle = 0.791E_{c10} = 22.15$  MeV) into 0.4 r.l of Ti.

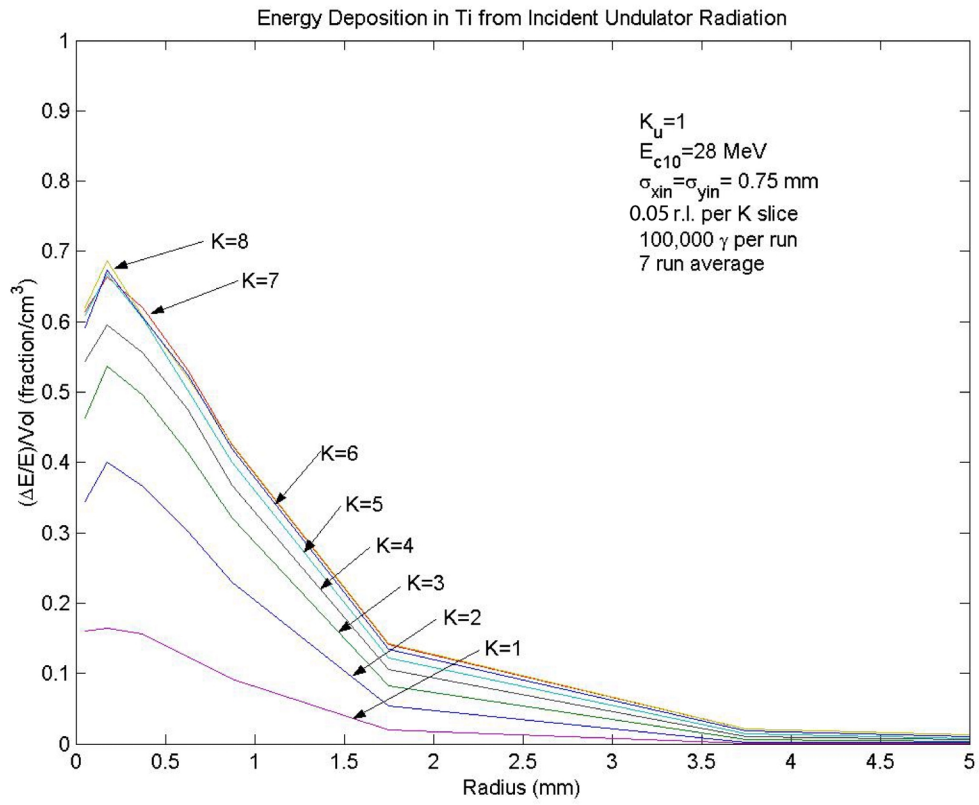


Figure 2a: Energy deposition in Ti due to incident undulator radiation,  $(\Delta E/E)/Vol$ .

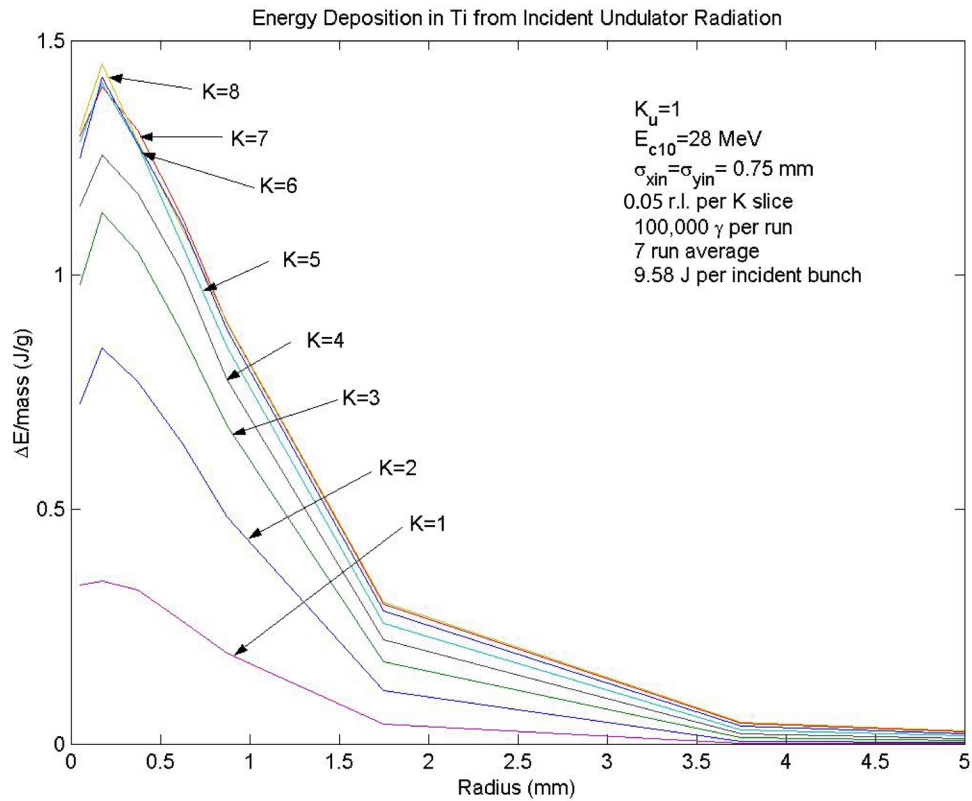


Figure 2b: Energy deposition in Ti due to incident undulator radiation,  $J/g$  for an incident total energy of 9.6 J. This corresponds to a single bunch from the TESLA undulator.

The peak energy deposition during a TESLA pulse is found by convoluting the K=8 curve of figure 2b (single bunch energy deposition in  $J/g$ ) with the TESLA bunch format (2820 bunches per pulse, spaced by 337 ns with a target speed of 50 m/s. The results are shown in Figure 3. (see Z:\positrons/egs4runs/ti\_spectrum/Tiedep\_multi.m)

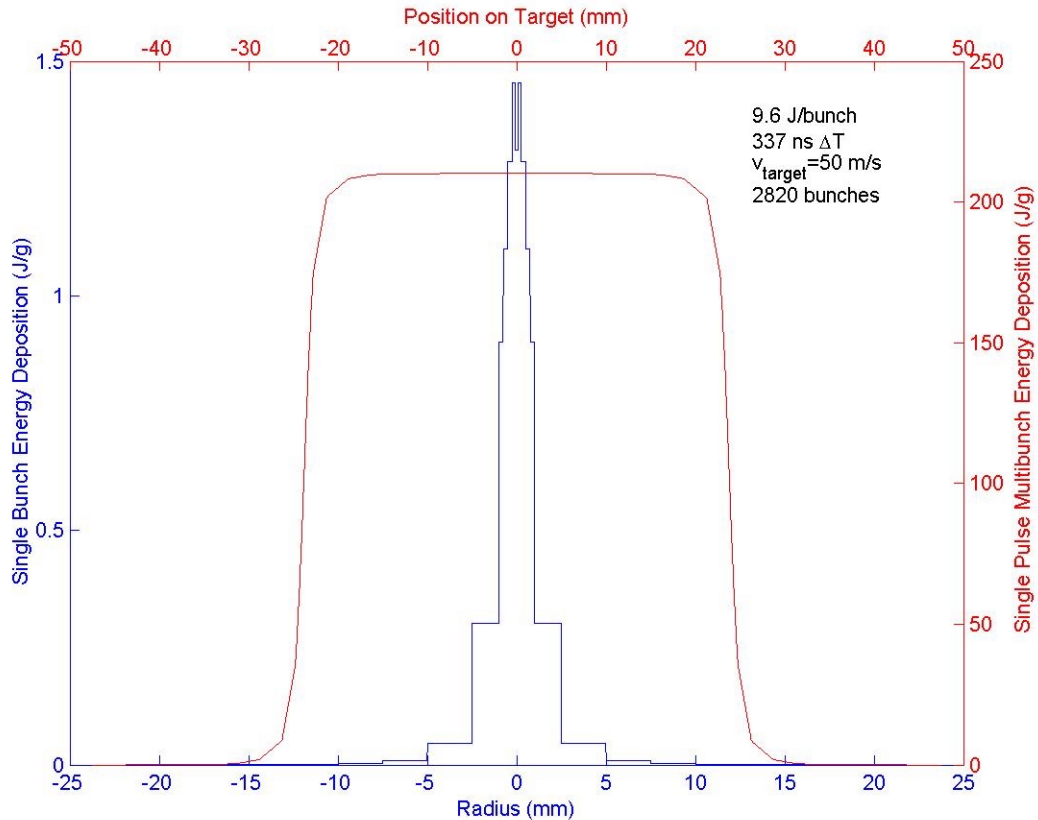


Figure 3.: Peak energy deposition in TESLA target for the single bunch (blue) and over the pulse train (red).

From figure 3, the peak single bunch deposition is about 1.5 J/g and during the train, the peak deposition comes out to be 208 J/g. This latter value is in nominal agreement with the published TESLA value of 222 J/g. The discrepancy is likely due to a larger incident spot size used in these examples 0.75 mm versus 0.70 mm rms in the TESLA TDR. (Simply scaling up by a factor of  $(0.75/0.70)^{1/2}$  brings the 208 J/g to 239 J/g. I made one run with 0.70 mm rms and the peak energy deposition in the core of the last slice is about 9% [227 J/g] greater than for the same seed and 0.75 mm rms incident size. If this is really an issue, I can rerun EGS4 using the smaller spot size).

Question: How does the energy deposition profile compare with the positron distribution in the target?

The 7 EGS4 run average has been saved as a text file in C:\matlab12\work\tiedata.txt. Z:\positrons/egs4runs/ti\_spectrum/tie\_profiles.m is used to make figures 4-6 which follow. Data files Z:\positrons/egs4runs/ti\_spectrum/tie\_profiles.m epsz05-40t.txt and input\_x\_y\_E.txt need to be loaded in. [Note, the original epsx\_0xx data files needed to be opened in WORDPAD and resaved as epsztxt.txt for data import into Matlab (go figure)].

To compare the energy deposition with the positron distribution, EGS4 was used to generate the positron positions at the exit face of a slab of Ti of specified thickness (0.05 r.l. to 0.40 r.l. in 8 steps corresponding to K=8)

[ /u/ad/jcs/egsrns/yieldcalc/phtnspctrm/ucRTZspc.mortran and /u/ad/jcs/egsrns/yieldcalc/phtnspctrm/ucRTZ1.data]. The input photon spectrum and photon beam size were for  $K_u=1$  undulator spectrum,  $E_{c10} = 28$  MeV, SIGX=SIGY=0.75 mm, random seeds IXX=1 and IYY=1 for all 8 runs, and 100,000 incident photons are used. The results of the egs4job.out10 files were transferred and edited and saved as epsz05t.txt, epsz10t.txt,.....epsz40t.txt in Z:\positrons/egs4runs/ti\_spectrum/. Z:\positrons/egs4runs/ti\_spectrum/input\_x\_y\_E.out6 has also been saved. The energy deposition and positron distributions for the 8 slices are shown in Figures 4a and 4b. There is "reasonable" congruence of the two profiles for most of the slices, some look better than others. The discrepancies are small.

The following table lists the rms positron beam sizes at the exit of the particular slice. These are determined using MATLAB std(epszxt(:,j)).

K	Filename (.txt and .out6)	Thickness (r.l.)	$\sigma_x$ (mm)	$\sigma_y$ (mm)
0	input_x_y_E	0	0.748	0.753
1	epsz05t	0.05	0.785	0.778
2	epsz10t	0.10	0.865	0.855
3	epsz15t	0.15	1.035	1.009
4	epsz20t	0.20	1.194	1.246
5	epsz25t	0.25	1.372	1.348
6	epsz30t	0.30	1.528	1.478
7	epsz35t	0.35	1.648	1.665
8	epsz40t	0.40	1.798	1.782

Table 1: Rms positron beam size through slab of Ti. See figures 4-6.

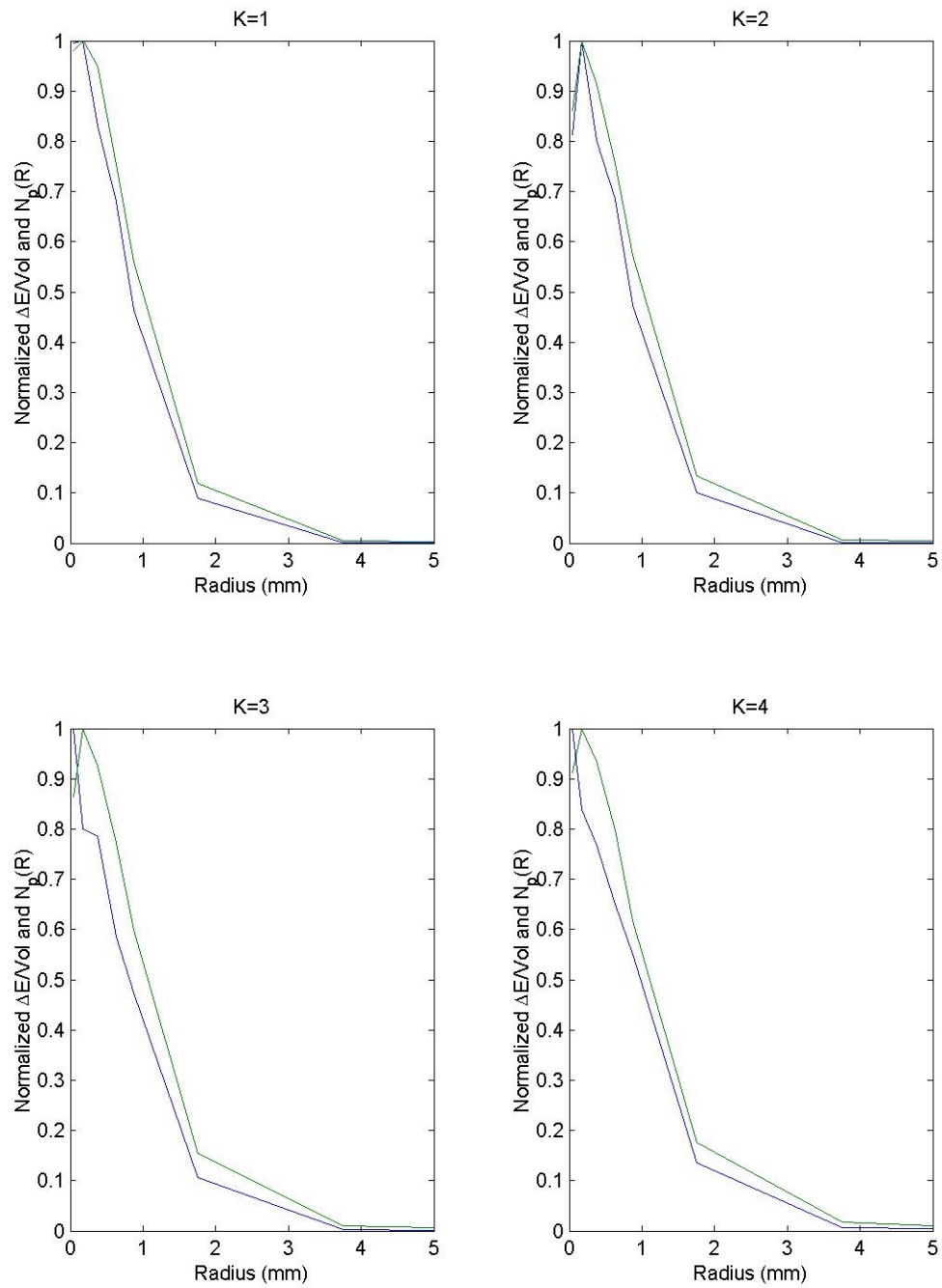


Figure 4a: Energy deposition profile (green) and positron distribution (blue) for K=1,4 slices (K=1 corresponds to 0.05 rl thickness, K=2 corresponds to 0.10 rl thickness,....)

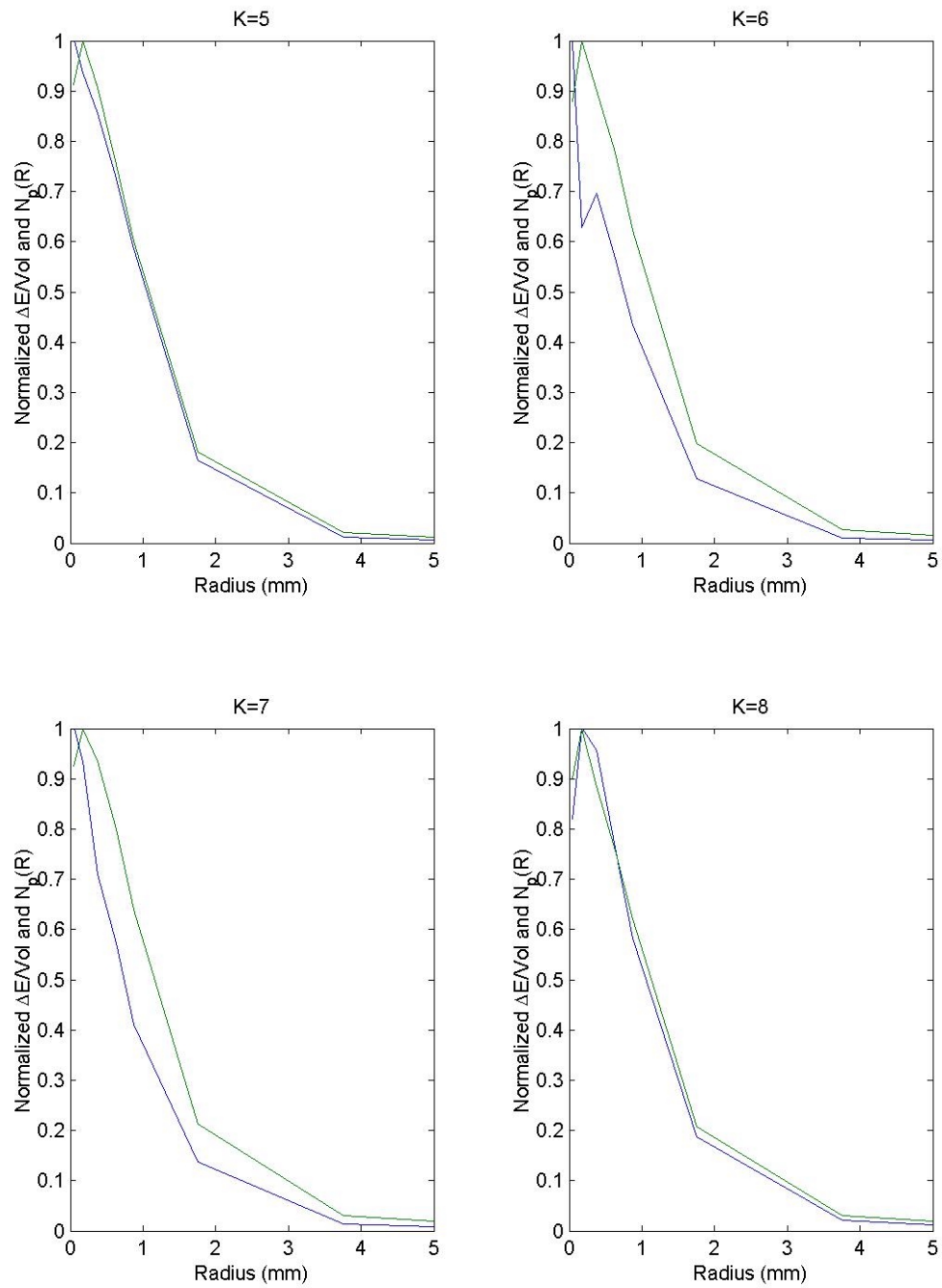
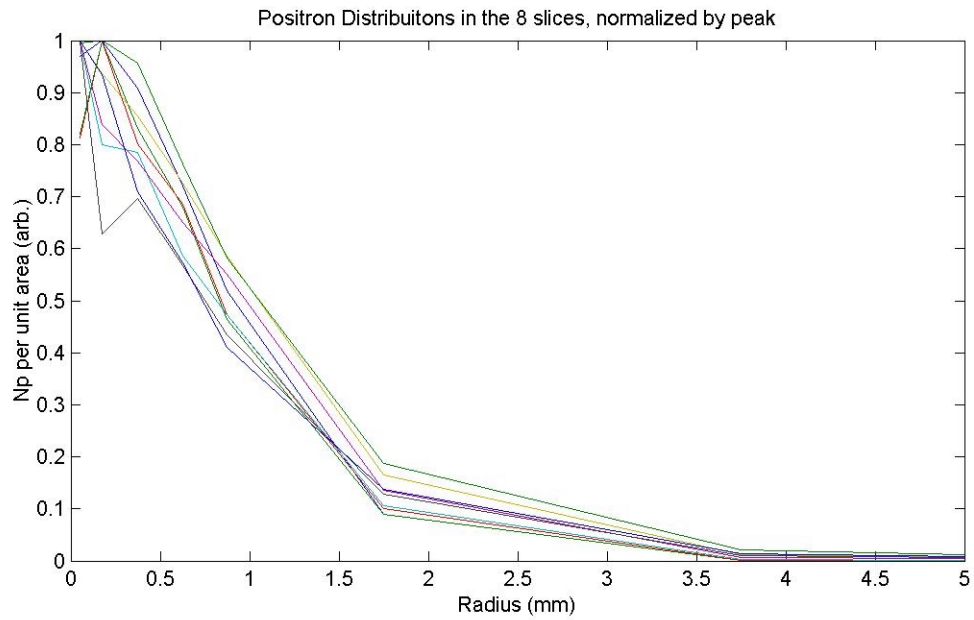
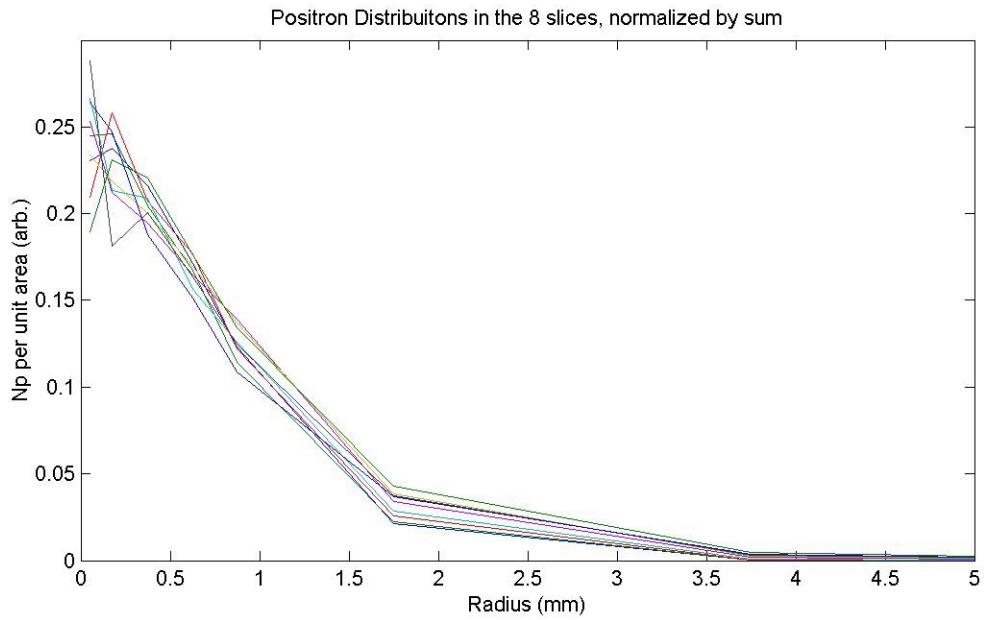


Figure 4b: Energy deposition profile (green) and positron distribution (blue) for K=5,8 slices (K=5 corresponds to 0.25 rl thickness, K=8 corresponds to 0.40 rl thickness,....)



Figures 5a (upper) and 5b (lower): The positron distributions in the various slices normalized by the area (aka sum) and by the peak. The input photon distribution,  $SIGX=SIGY=0.75$  mm is also included in the figures.

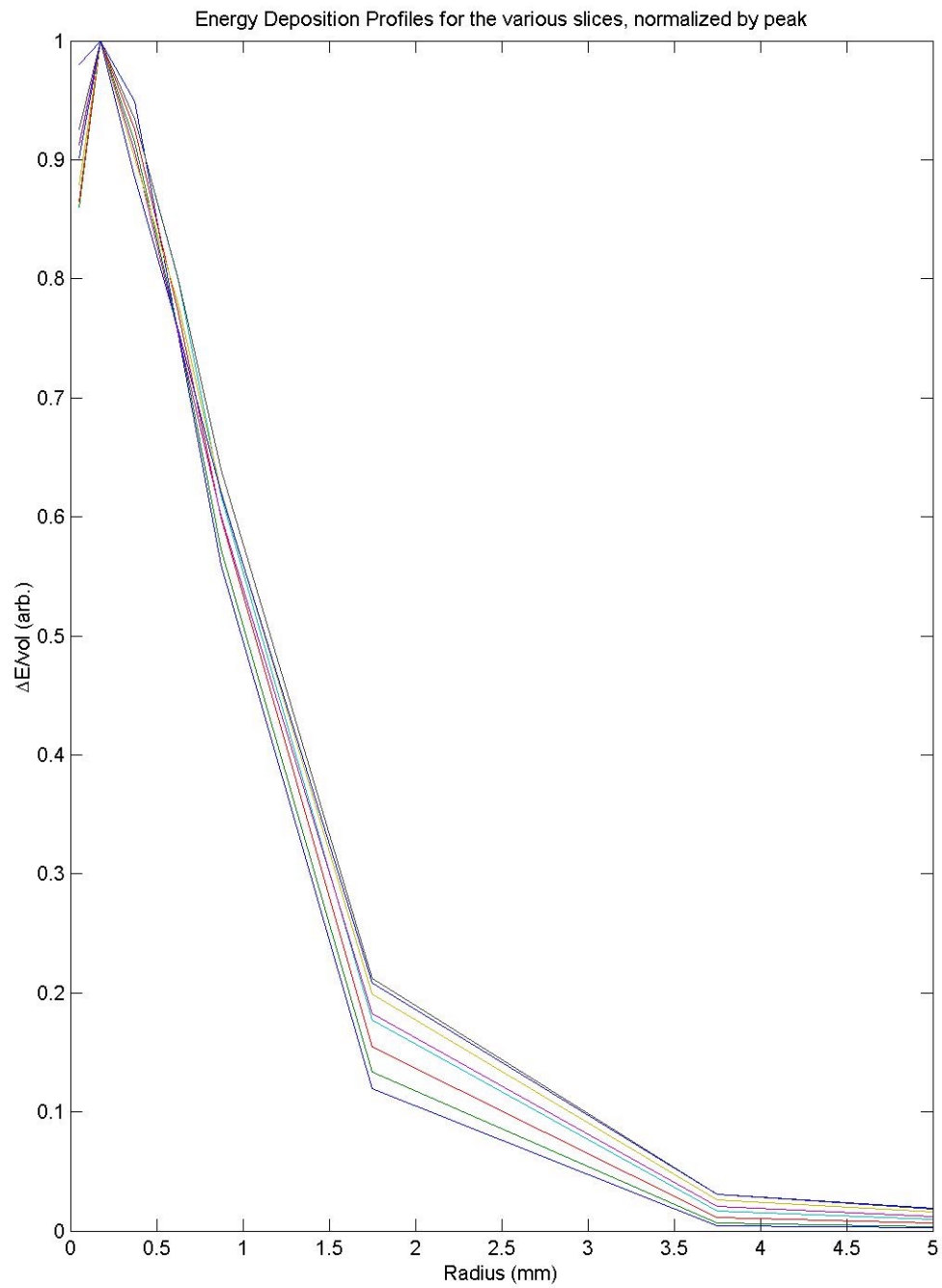


Figure 6: The energy deposition profiles for the 8 slices, normalized by the peak.

Yuri asked the question, how does the electron distribution compare with the positron distributions. They look virtually identical despite the fact that there are 50%-60% more electrons than positrons. For figures 7 and 8, ucRTZspc.mortran and ucRTZespc.mortran were used to calculate the positron and electron distributions at the exit of the slices, using the same input data file. One random seed, Ixx=1 and Jxx=1 was used.

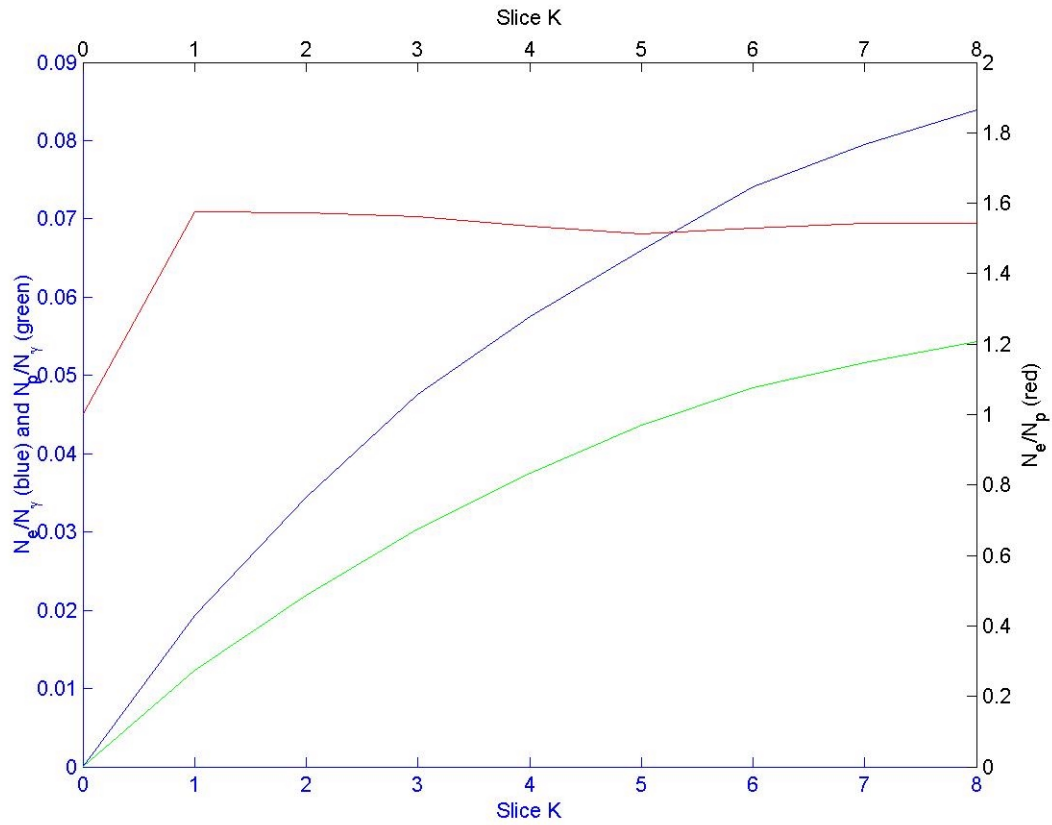


Figure 7 shows the number of positrons and electrons exiting a slice and the ratio of the number of electrons to positrons.

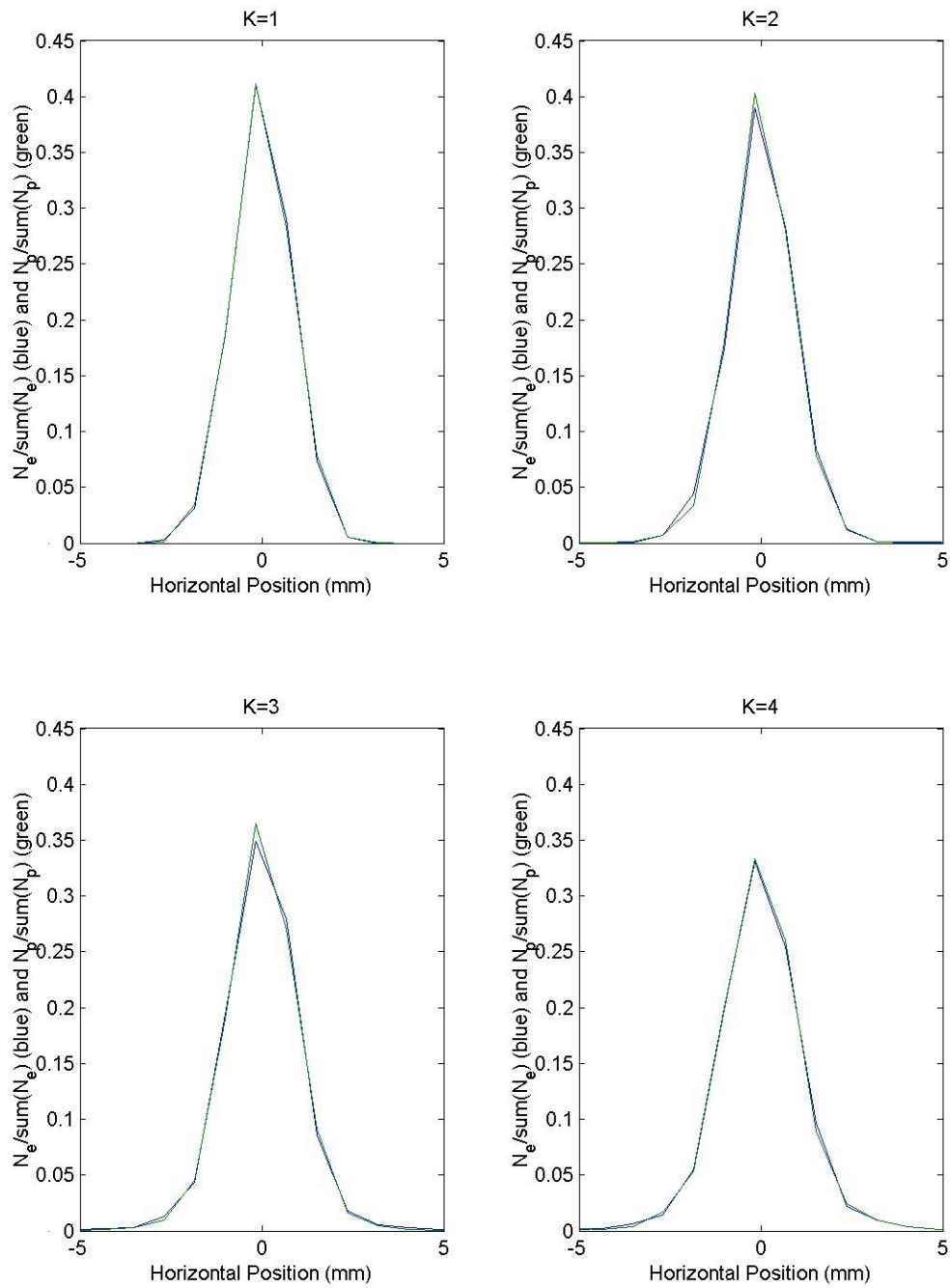


Figure 8a: The horizontal distributions of electrons (blue) and positrons (green) at the exit of slices K=1,4

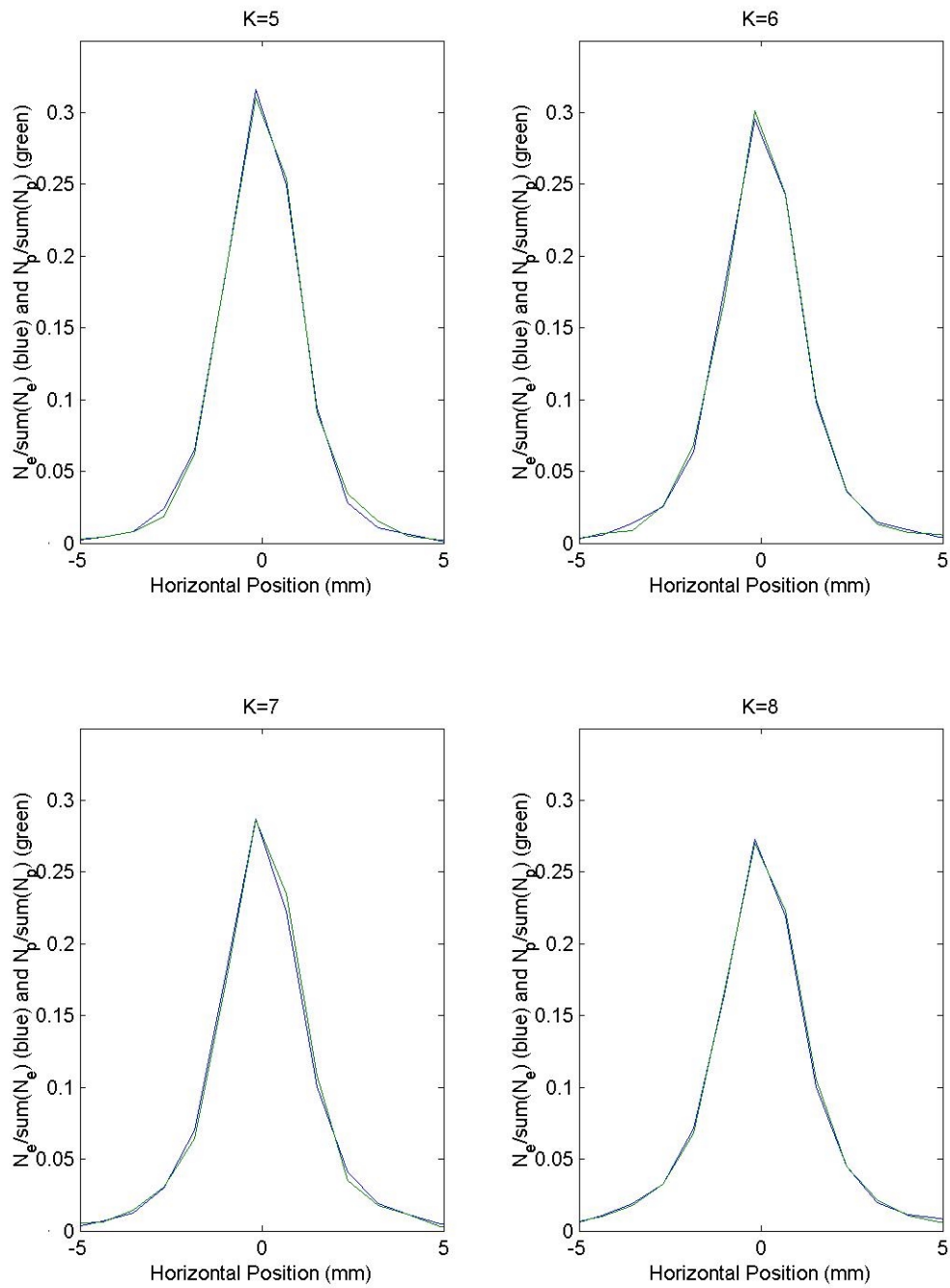


Figure 8b: The horizontal distributions of electrons (blue) and positrons (green) at the exit of slices K=5,6

Table 2: Useful AFS files for EGS4 runs

Filename	Comments
./ucRTC_temp/ucRTZ_temp.mortran	Calc. energy deposition, pencil beam
./ucRTC_temp/ucRTZ_temp.data	input data file
./ucRTZ_temp_spctry.mortran	Calc. energy deposition, input gaussian beam size, $K_u=1$ energy spectrum
./ucRTZ_temp_spctry.data	input data file
./ucRTZspc.mortran	Calc. $e^+, e^-$ , or $\gamma$ production, input gaussian beam size, $K_u=1$ energy spectrum
./ucRTZ1.data	input data file
./pncum_k1_120.out	cumulative $K_u=1$ undulator spectrum, read in and used to calc. incident photon energies
./ww10c_k1_120.out	normalized photon energies, used with ./pncum_k1_120.out to calc. incident photon energies
./input_x_y_E.out	incident $I_{cases}$ x,y position and energy, written by EGS4 at CALL SHOWER
./egs4job.out10	principal EGS4 output file

./ = /u/ad/jcs/egsruns/

./ = /u/ad/jcs/egsruns/yeildcalc/phtnspctrm/