Joint ICTP-IAEA Workshop on Monte Carlo Radiation Transport and Associated Data Needs for Medical Applications
28 October – 8 November 2024
ICTP, Trieste, Italy

Lecture 15

BEAMnrc sources and component modules

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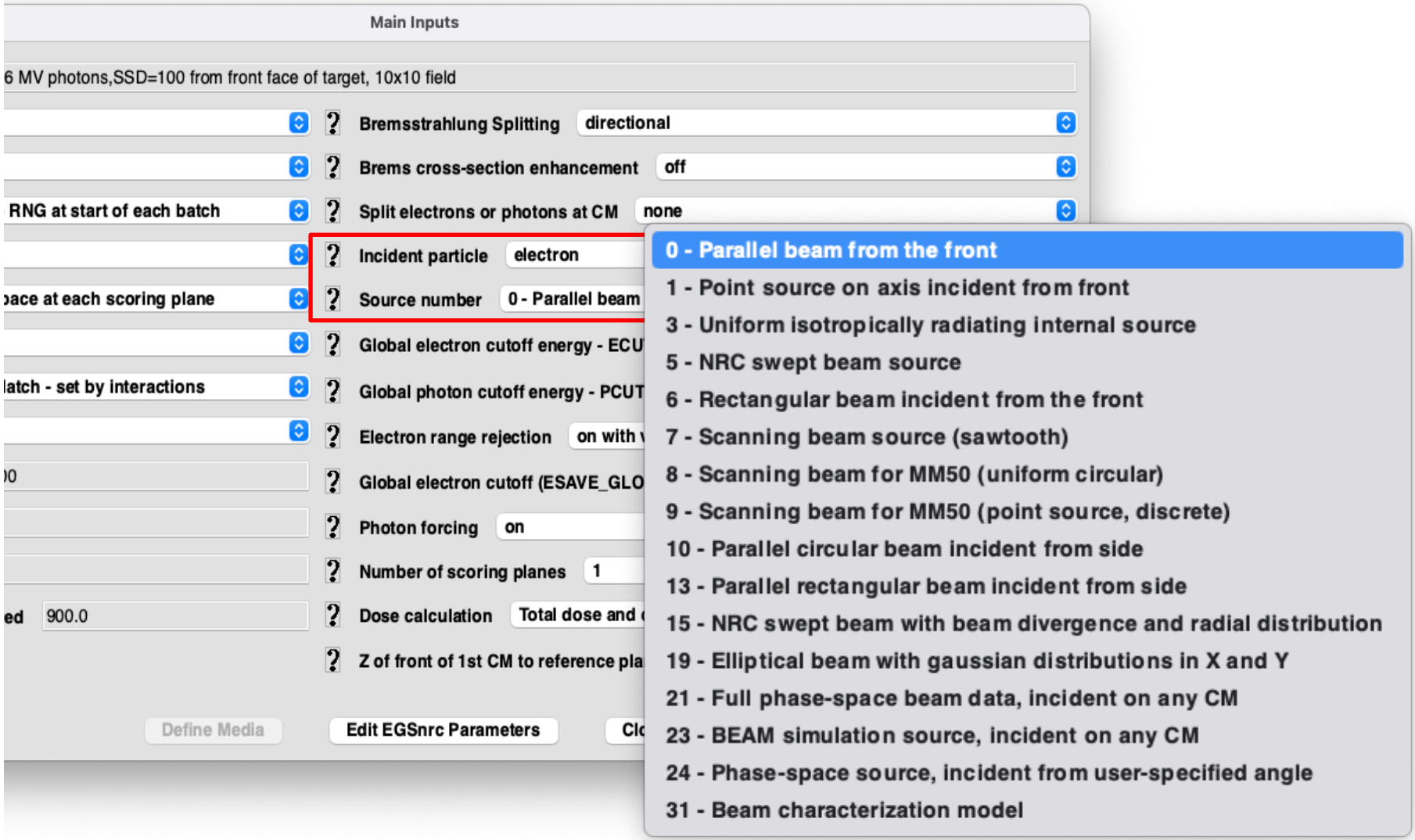
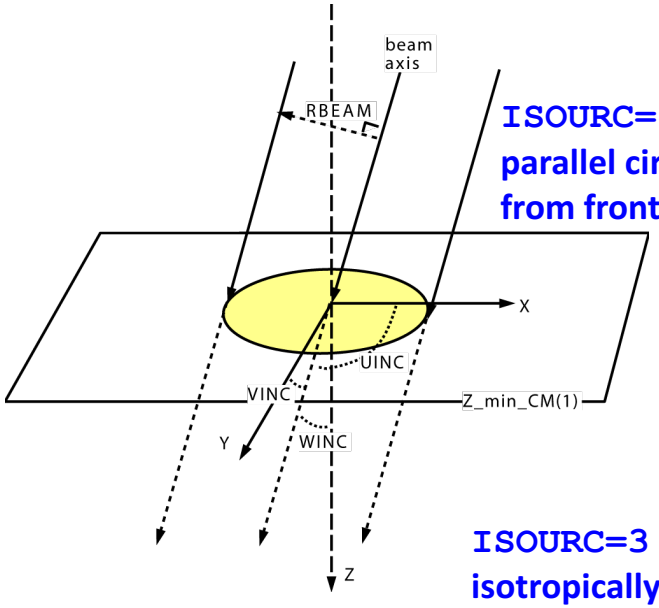
Sources

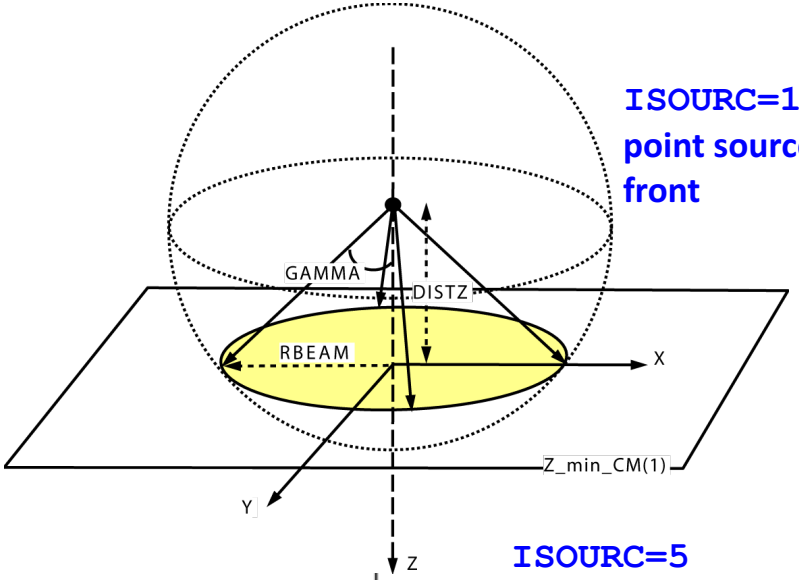
Main BEAMnrc GUI Window



Primary source collection

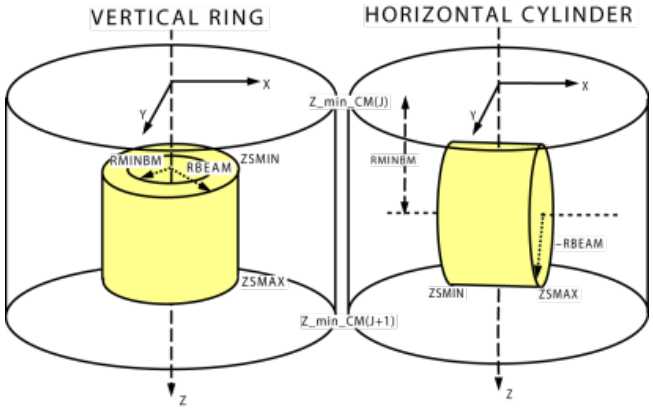


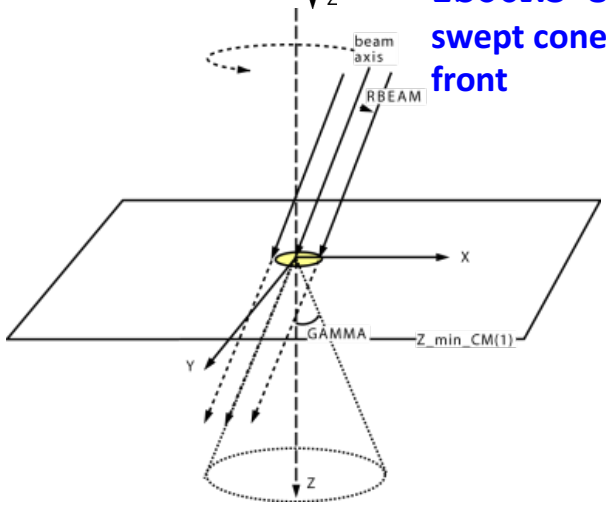
ISOURC=0
parallel circular beam from front



ISOURC=1
point source from front

ISOURC=3
isotropically radiating volume

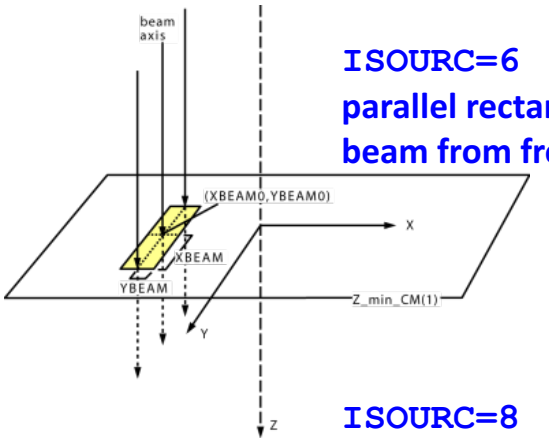




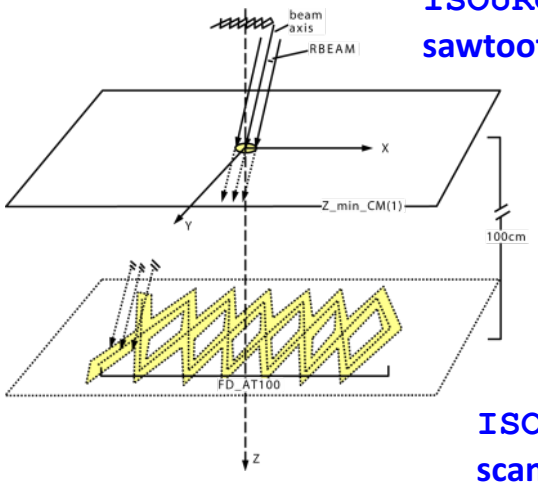
ISOURC=5
swept cone from front

Primary source collection (cont.)

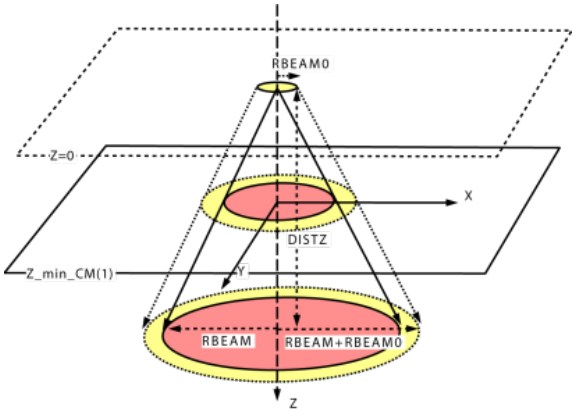
ISOURC=6
parallel rectangular beam from front



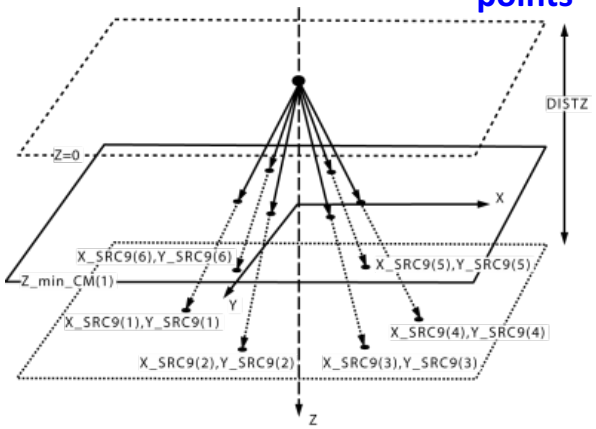
ISOURC=7
sawtooth



ISOURC=8
scanned pt. source

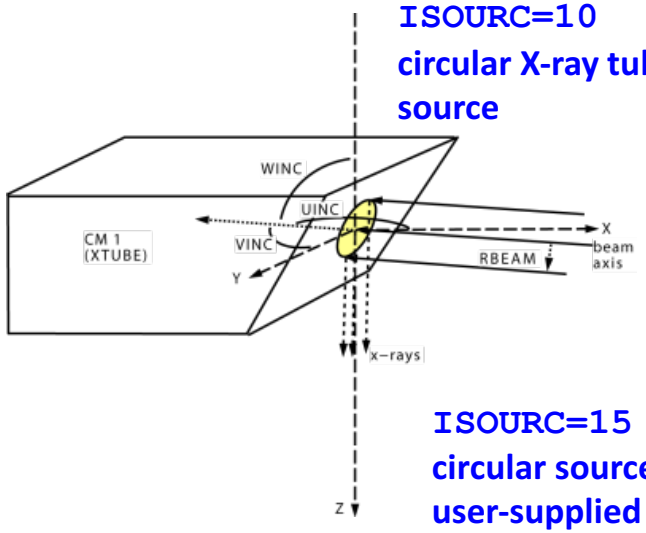


ISOURC=9
scanned discrete points

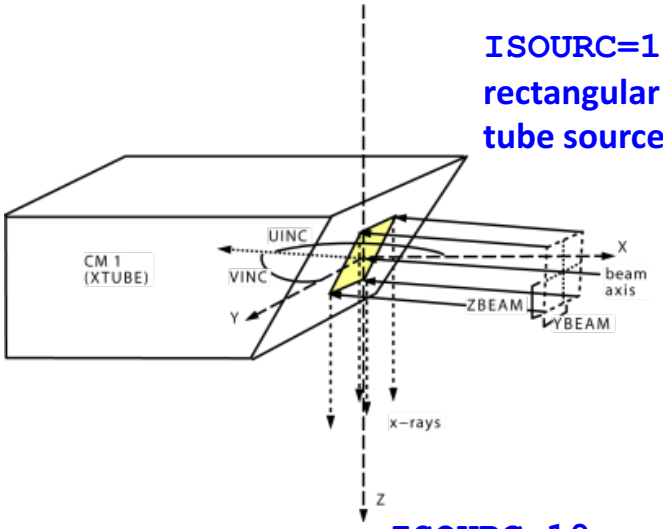


Primary source collection (cont.)

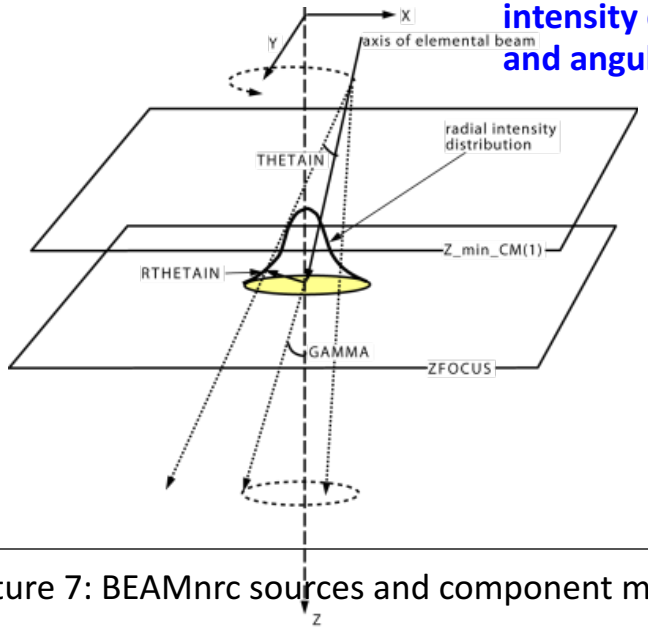
ISOURC=10
circular X-ray tube source



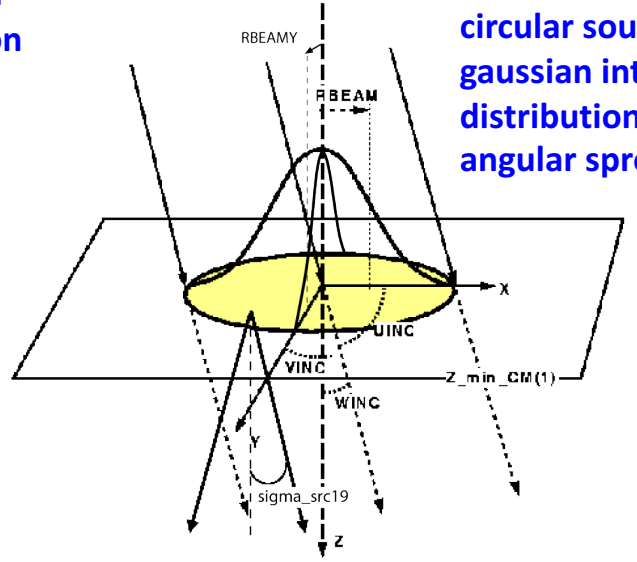
ISOURC=13
rectangular X-ray tube source



ISOURC=15
circular source with user-supplied radial intensity distribution and angular spread

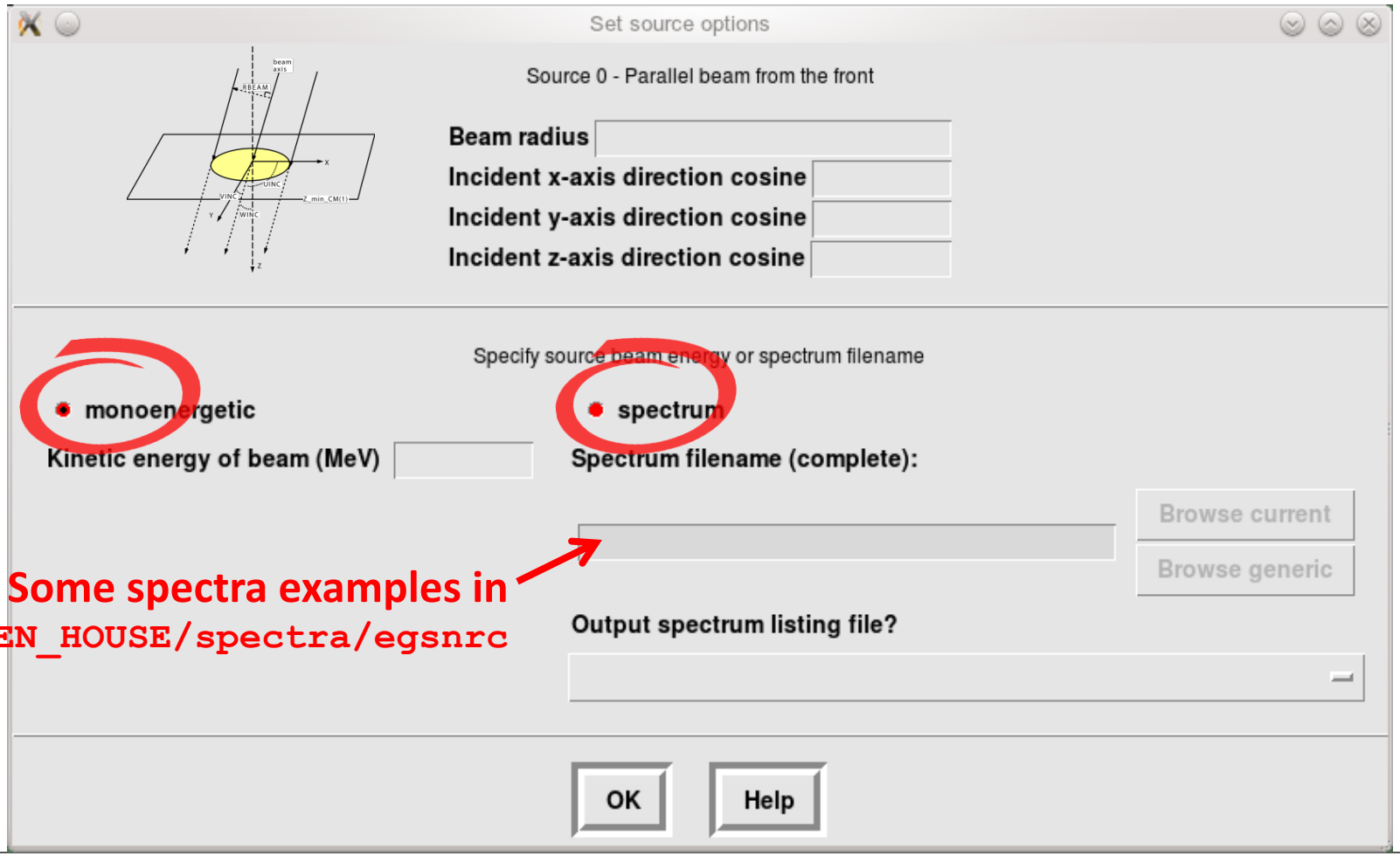


ISOURC=19
circular source with gaussian intensity distribution & angular spread



Primary sources

- **Can be monoenergetic or have an energy spectrum**



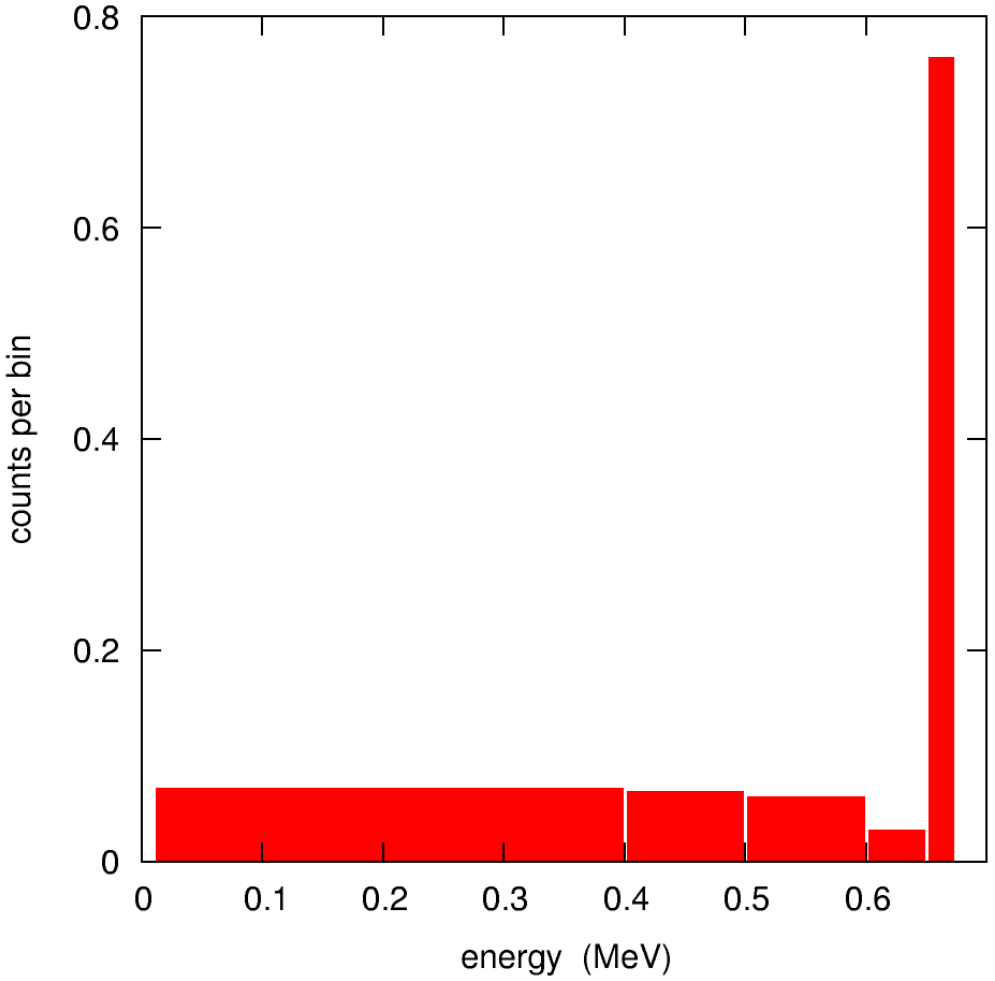
Some spectra examples in
`$HEN_HOUSE/spectra/egsnrc`

The energy spectrum is a simple (x,y) text file

TITLE
N, EMIN, MODE
E(1), P(1)
E(2), P(2)
E(3), P(3)
...
E(N), P(N)

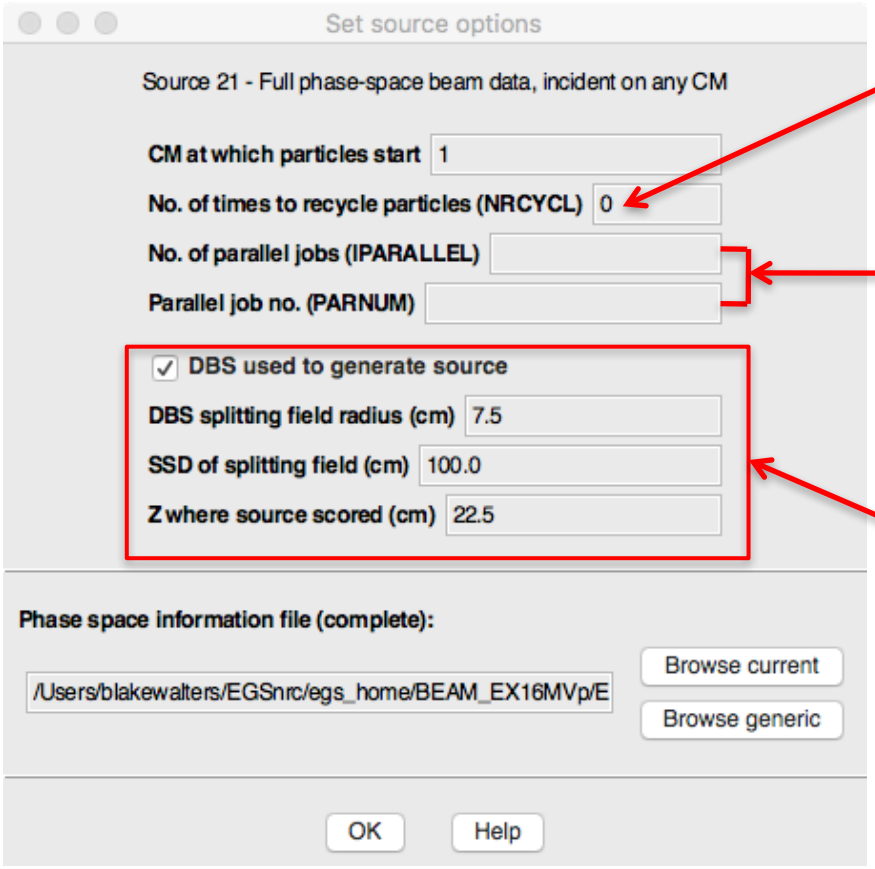
TITLE	80-character title
N	number of energy bins
EMIN	lower energy of first bin (MeV)
MODE	0 (counts/bin), 1 (counts/MeV)
E(i)	upper energy of bin (MeV)
P(i)	probability of bin (does not need to be normalized)

The energy spectrum is a simple (x,y) text file




```
My spectrum
5, 0.01, 0
0.400, 0.0721
0.500, 0.0687
0.600, 0.0639
0.650, 0.0319
0.674, 0.7634
```

Phase space source (ISOURC=21)

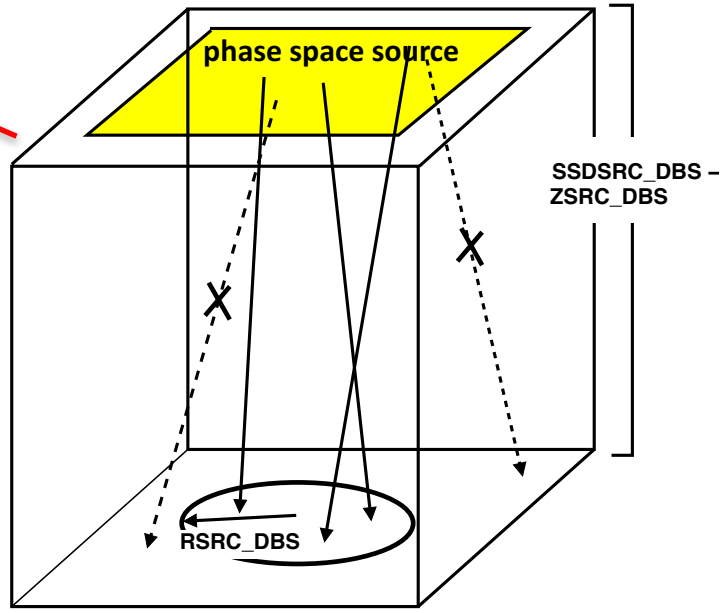


If set to 0 (blank)

NRCYCL = NCASE / NPHSP

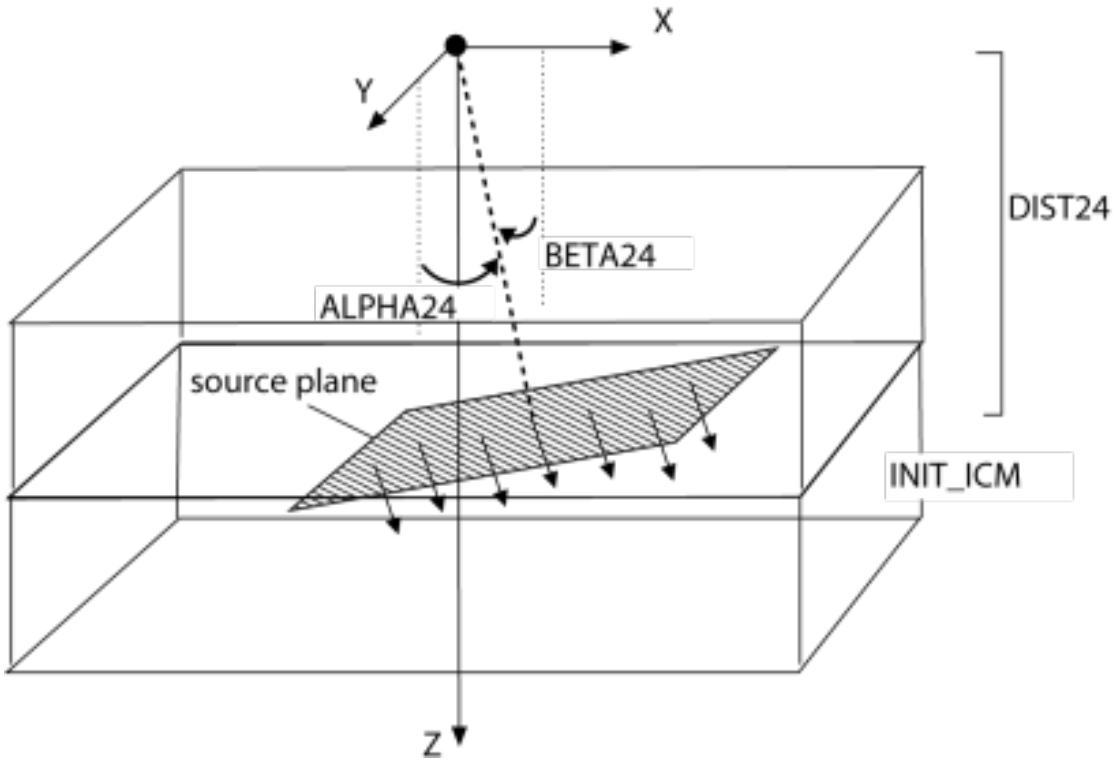
No longer used

Required to reject phat photons



- One of the most common uses of BEAMnrc is simulating downstream components using a previously generated (vendor supplied) phase space file

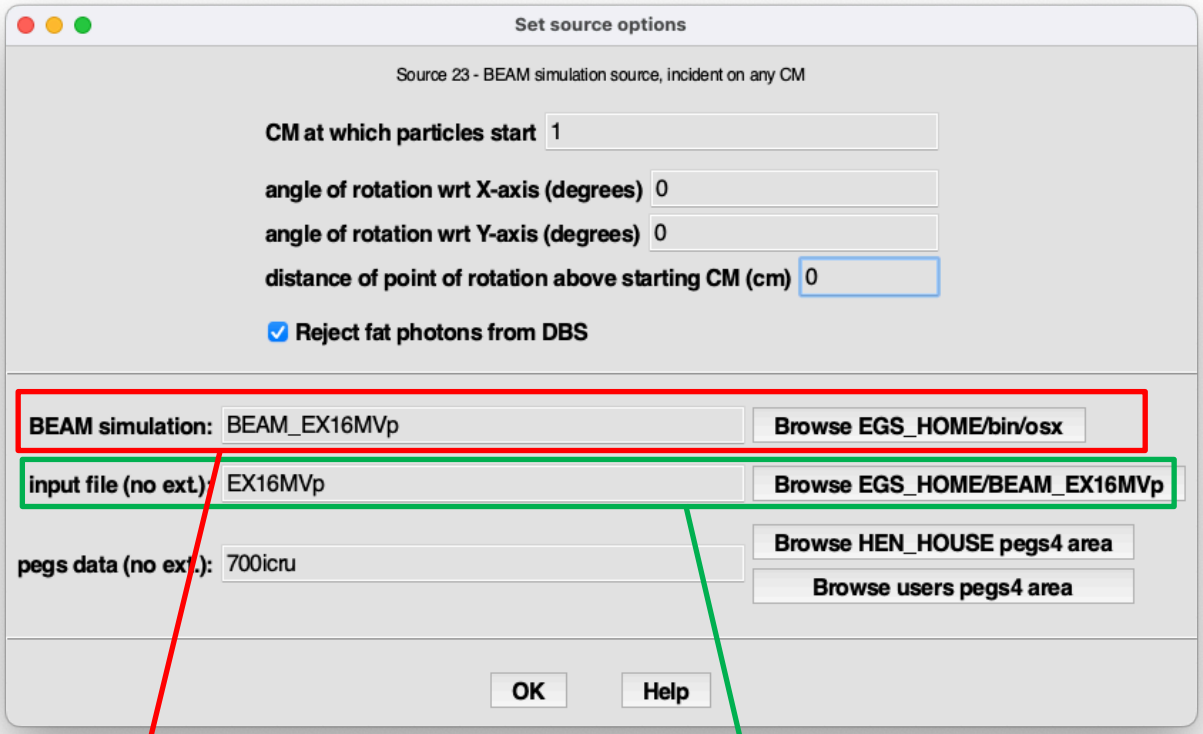
Tilted phase space source (ISOURC=24)



After tilting, particles must be incident within CMs that can handle internal sources: SLABS, SIDETUBE, FLATFILT, CONESTAK

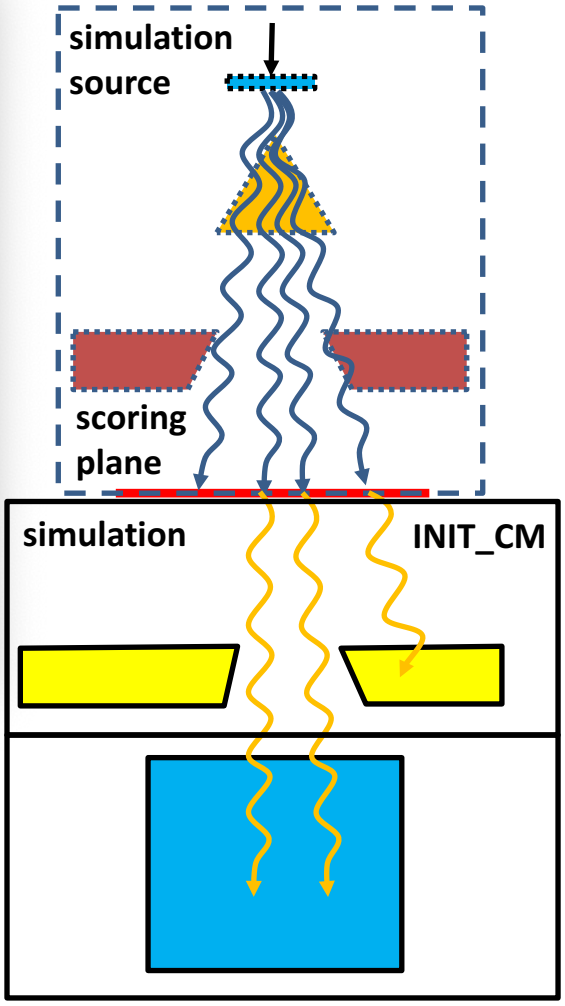
This is also true for ANY phase space source using a non-planar IAEA format phase space file (i.e. particles scored with variable Z)

BEAM simulation source (ISOURC=23)



Compiled as shared library

Must exist in source's BEAM_accelname directory

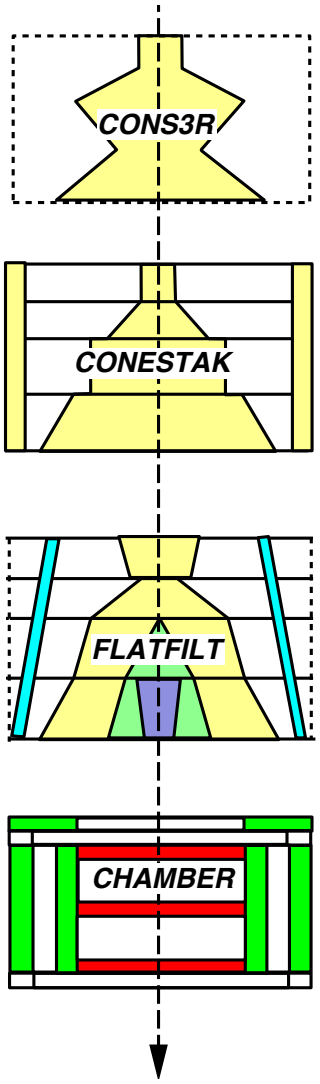


Component Modules

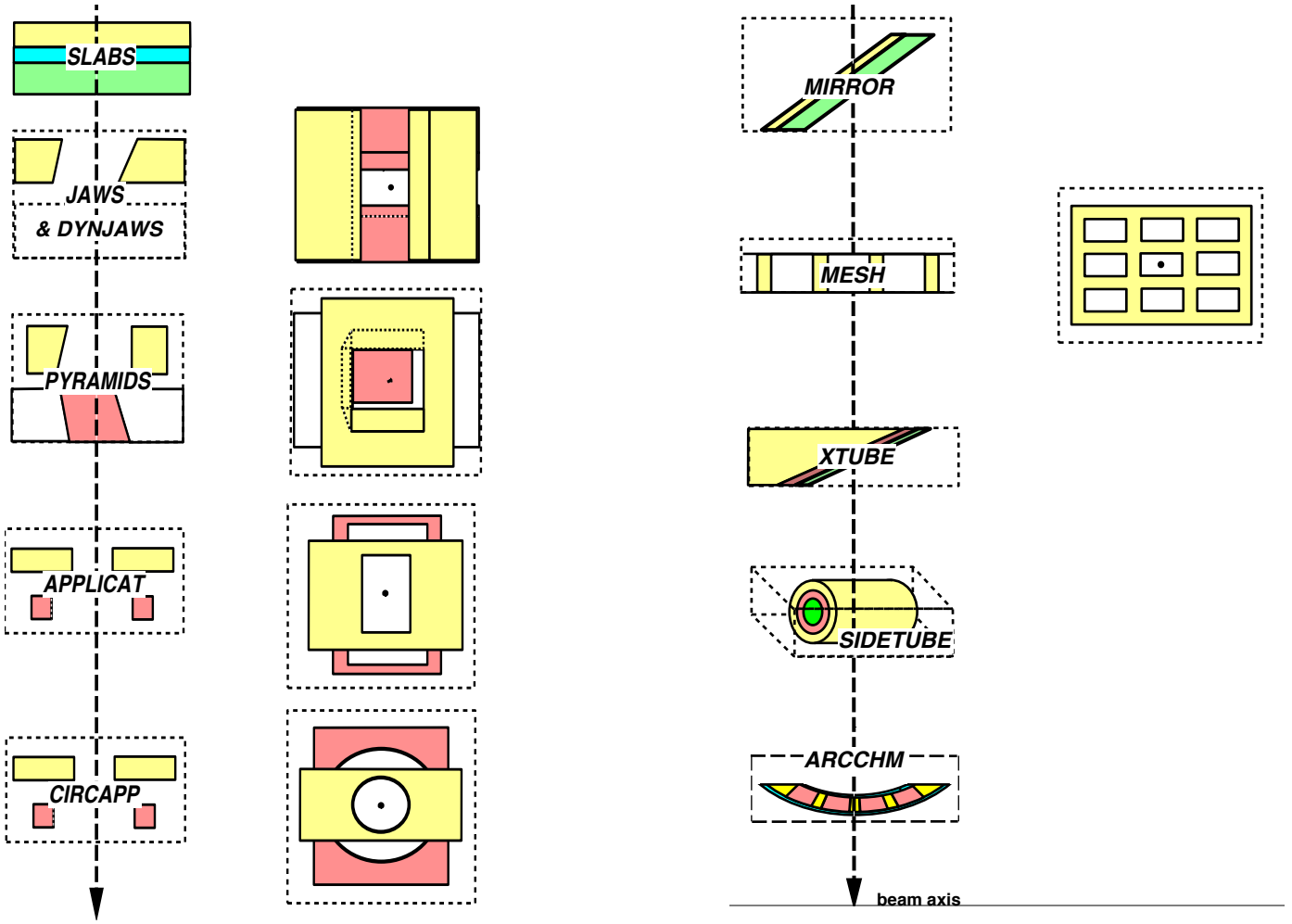
What are Component Modules (CMs)?

- **Blocks of MORTRAN (sorry) code optimized for simulating typical accelerator components**
- **Stacked on top of one another to create an accelerator**
- **Outer boundaries always centred on beam (Z) axis**

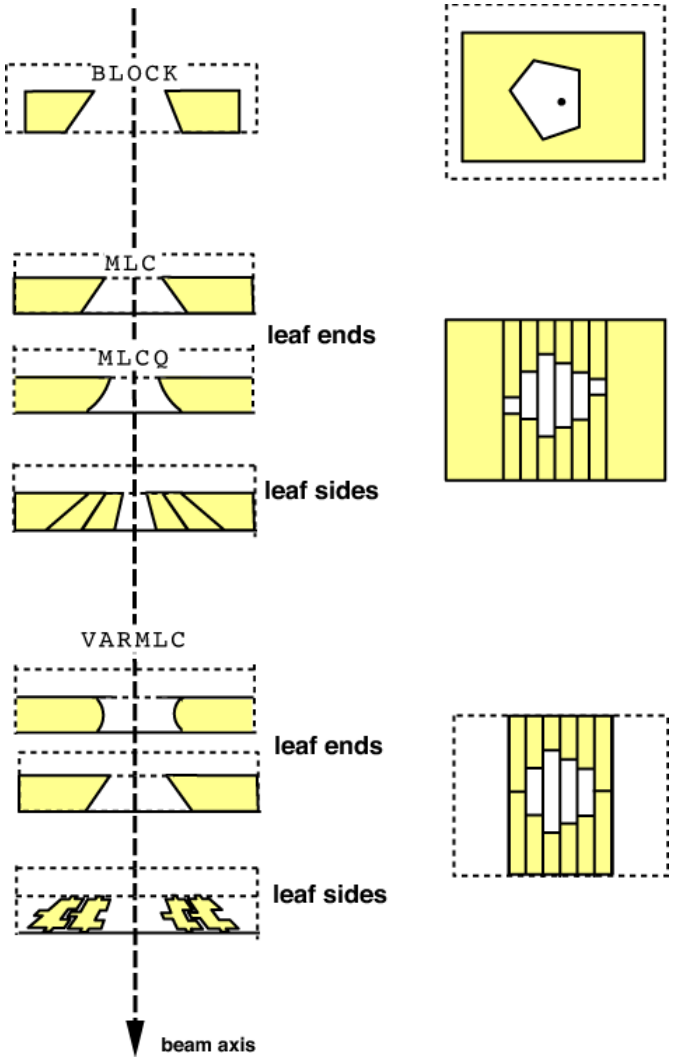
Cylindrical component modules

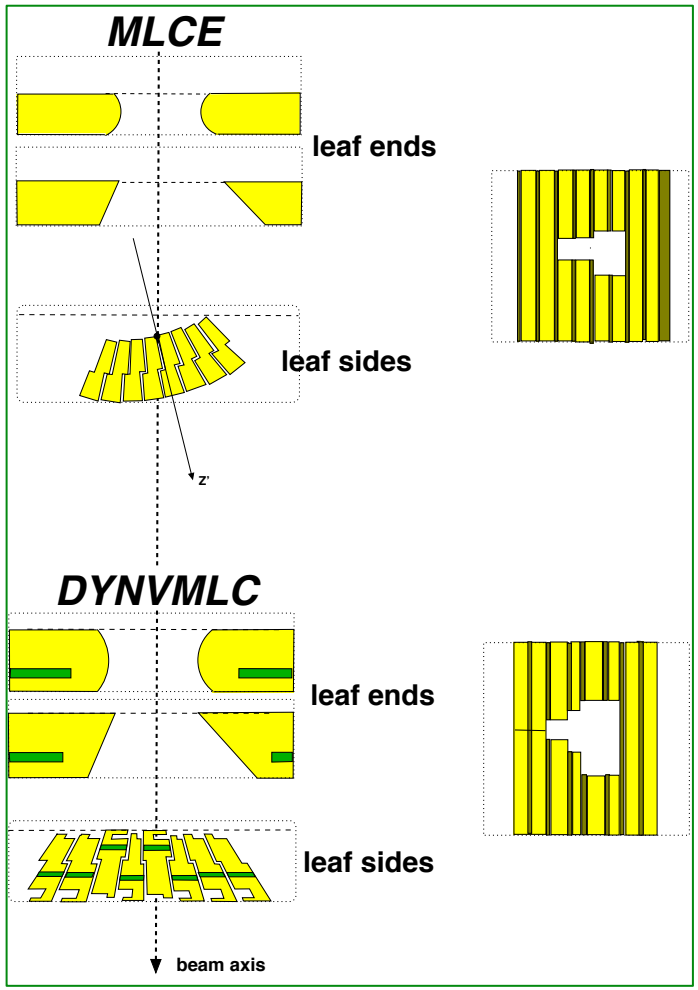


Square component modules



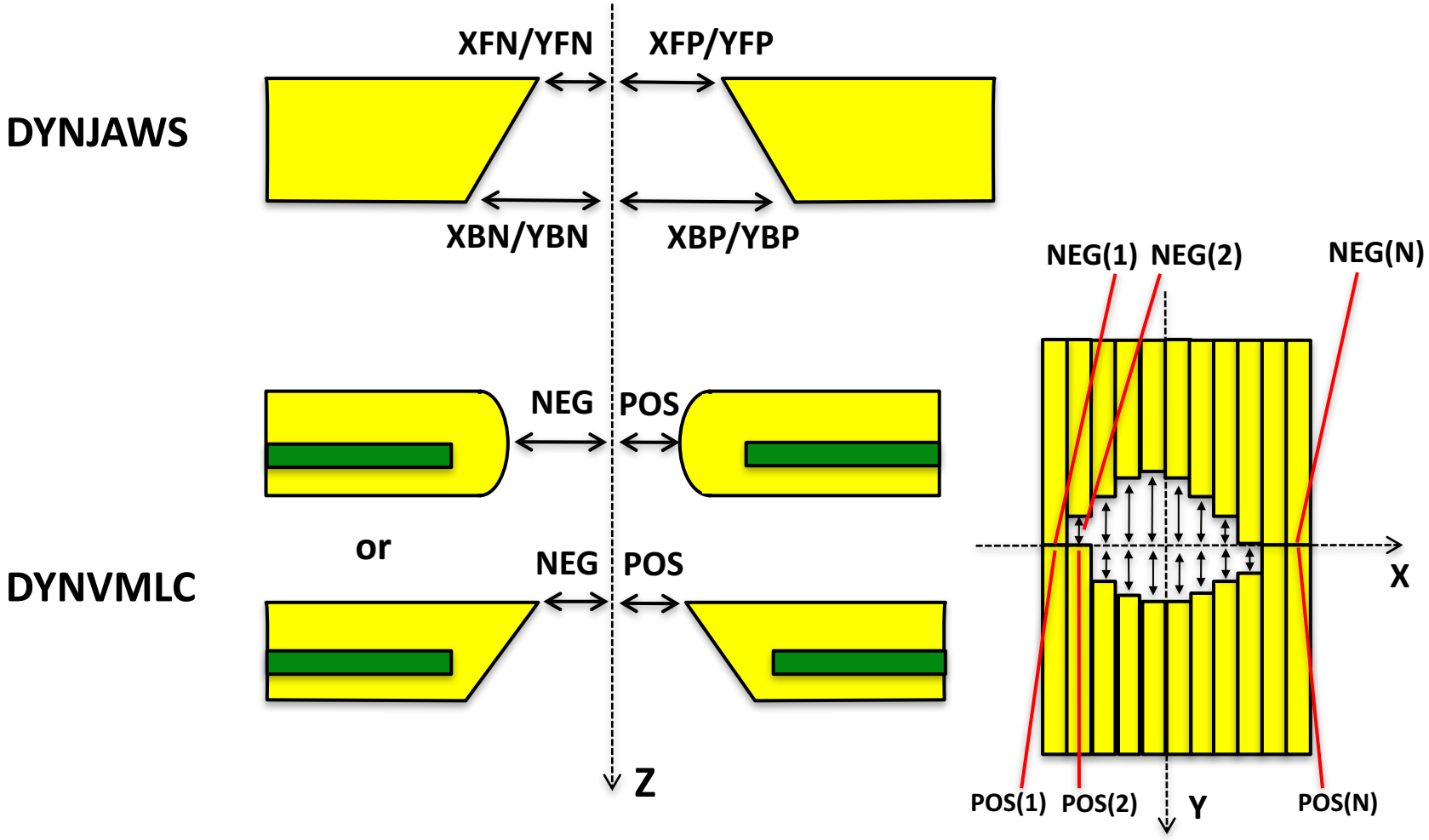
Multi-leaf collimators





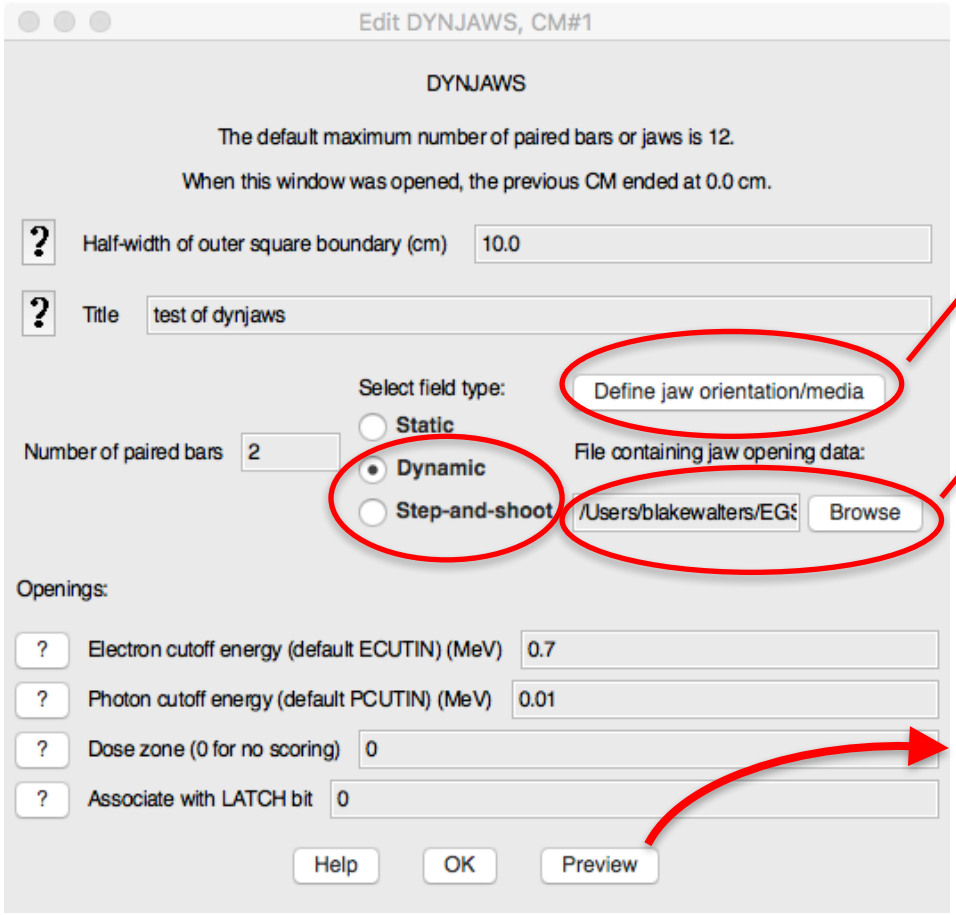
Dynamic component modules

"time" varying opening coordinates



Dynamic component modules (cont.)

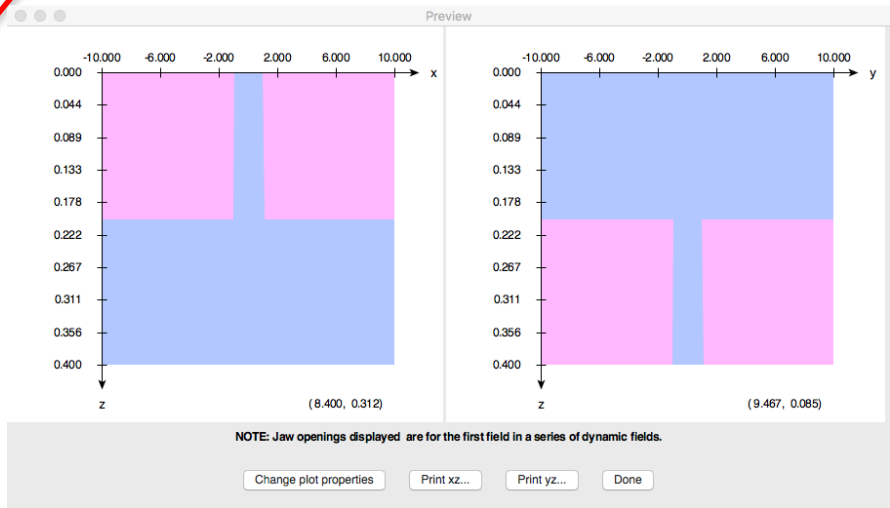
GUI inputs



Still need to define jaw orientation/media

Opening dimensions for each field defined in a file

Preview shows first field defined



Dynamic component modules (cont.)

Format for file of field definitions

```
Ex: 4 fields, 2 jaws, equal prob.   <-- title
4                                   <-- no. fields
0.0                                 <-- fractional monitor unit index (INDEX)
0.001, 0.2, 1, 1.1, -1, -1.1        <-- ZMIN(1), ZMAX(1), XFP(1), XBP(1), XFN(1), XBN(1)
0.201, 0.2, 1, 1.1, -1, -1.1        <-- ZMIN(2), ZMAX(2), YFP(2), YBP(2), YFN(2), YBN(2)
0.33
0.001, 0.2, 1, 1.1, -1, -1.1
0.201, 0.2, 2, 2.1, -2, -2.1
0.66
0.001, 0.2, 2, 2.1, -2, -2.1
0.201, 0.2, 1, 1.1, -1, -1.1
1.0
0.001, 0.2, 2, 2.1, -2, -2.1
0.201, 0.2, 2, 2.1, -2, -2.1
```

field 1

field 2

field 3

field 4

Restrictions on INDEX for field i:

- `INDEX(1) >= 0.0` <-- should be 0.0 unless doing step-and-shoot
- `INDEX(i+1) >= INDEX(i)`
- `INDEX(N) = 1.0`

Sample sequence files can be found in
`$OMEGA_HOME/beamnrc/CMs/sample_sequences`

Dynamic component modules (cont.)

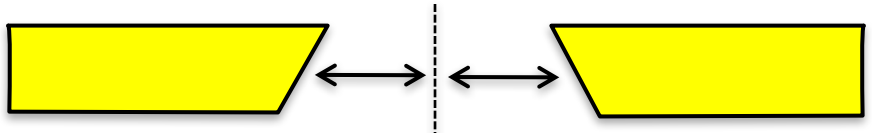
Field selection

- **random fractional monitor unit (MU) ∈ [0,1) selected at the beginning of each primary history**
- **for field, i, where INDEX(i-1) < MU ≤ INDEX(i), dimension parameter, P (P≡ xfp, xbp,…), is chosen using:**

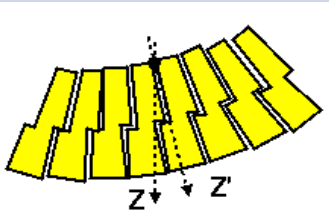
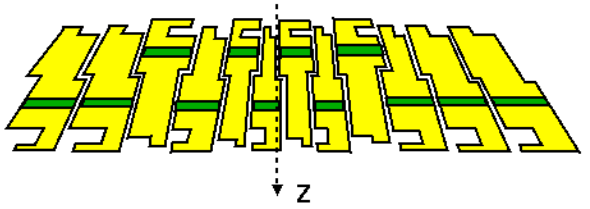
Method	Eqn
step-and-shoot	$P = P_i$
dynamic	$P = P_{i-1} + \frac{P_i - P_{i-1}}{\text{INDEX}_i - \text{INDEX}_{i-1}} \times (\text{MU-INDEX}_{i-1})$

Synchronized component modules

Lobo & Popescu, *Phys Med Biol* 55:4431—4443



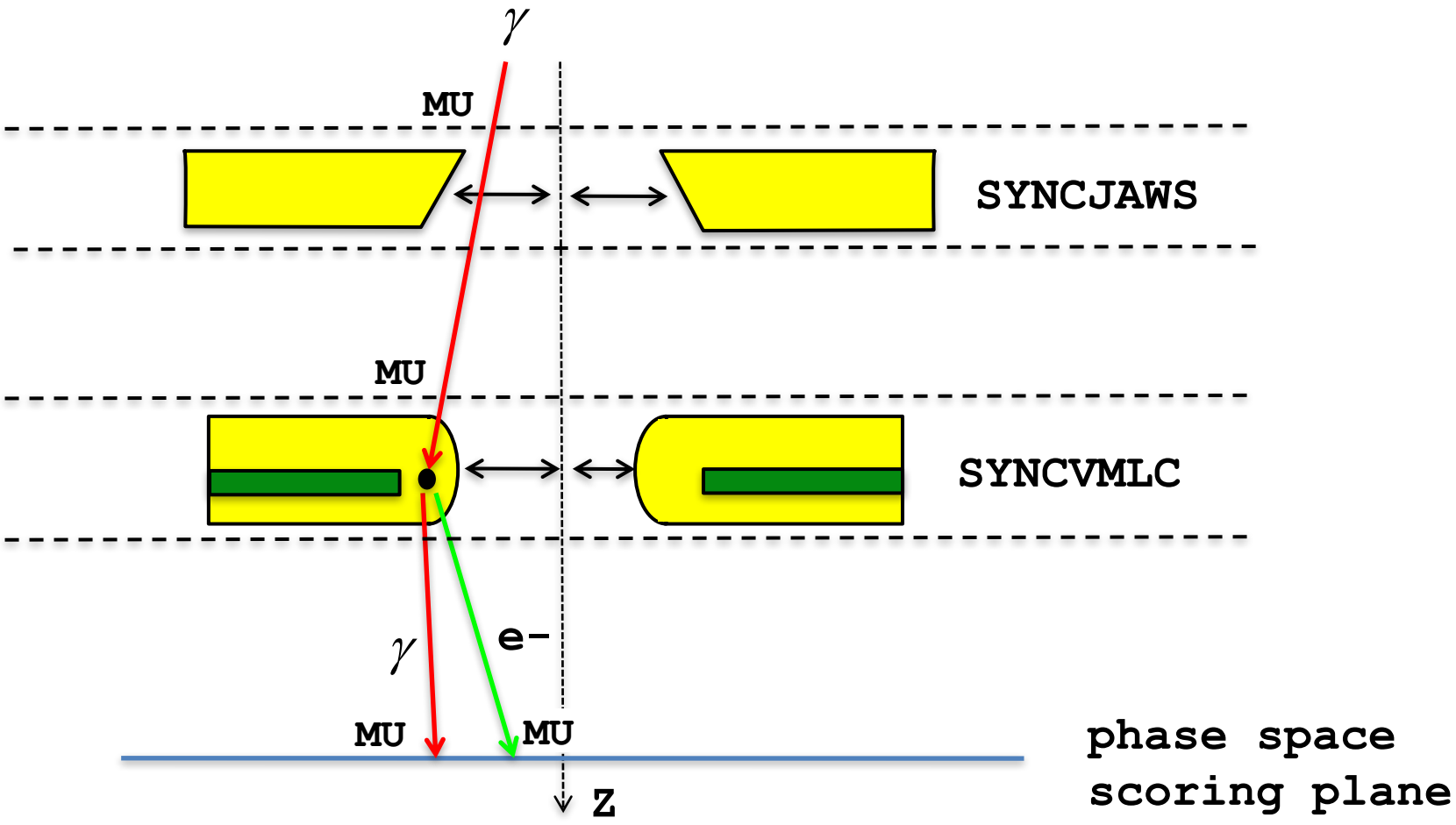
SYNCJAWS

mlc type	leaf ends	leaf x-section (define once)
SYNCMLCE		
SYNCVMLC	or 	
SYNCHDMLC		

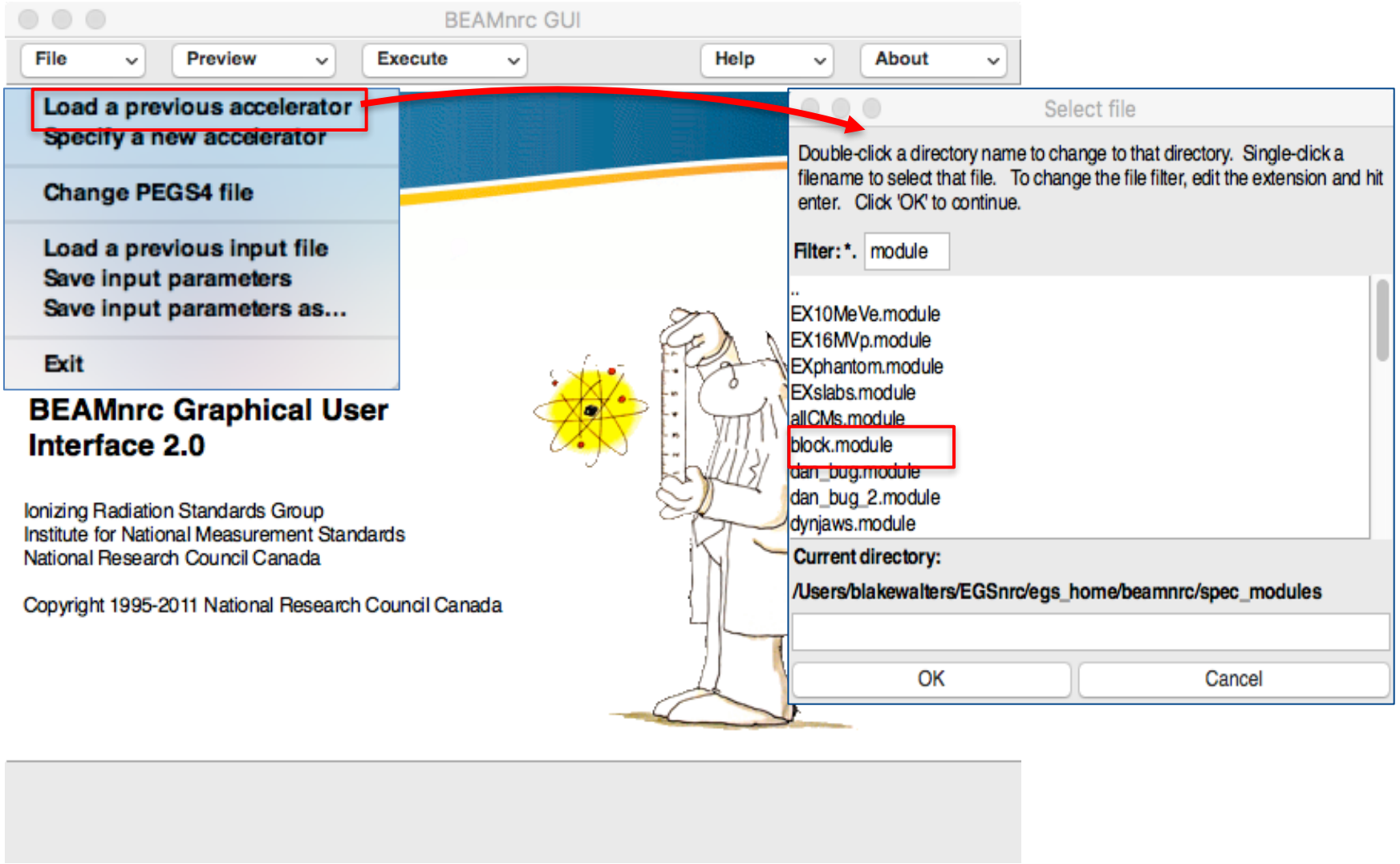
z

Synchronized component modules (cont.)

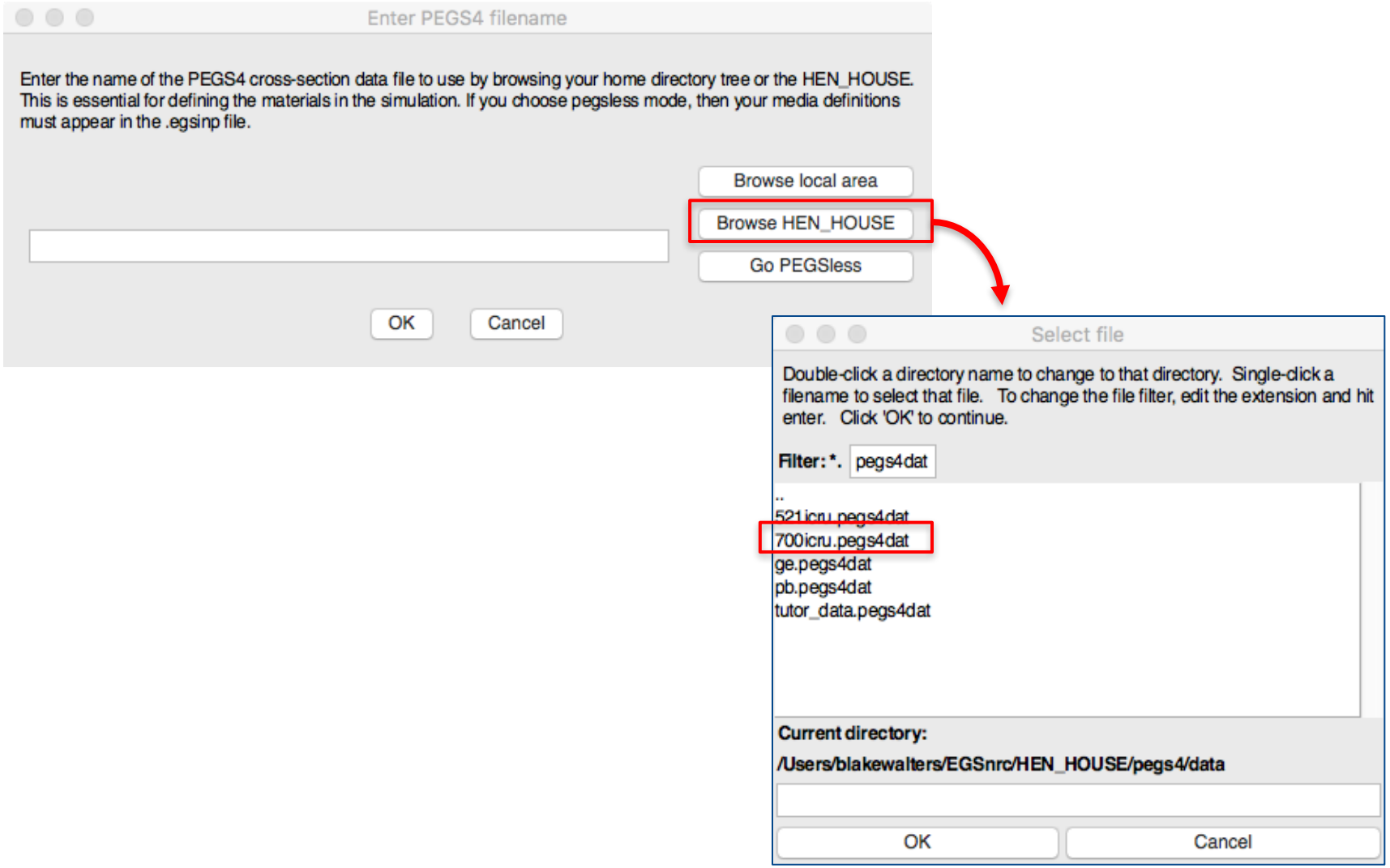
- **For each particle (and its descendants) the same value of MU is used for all synchronized CMs**



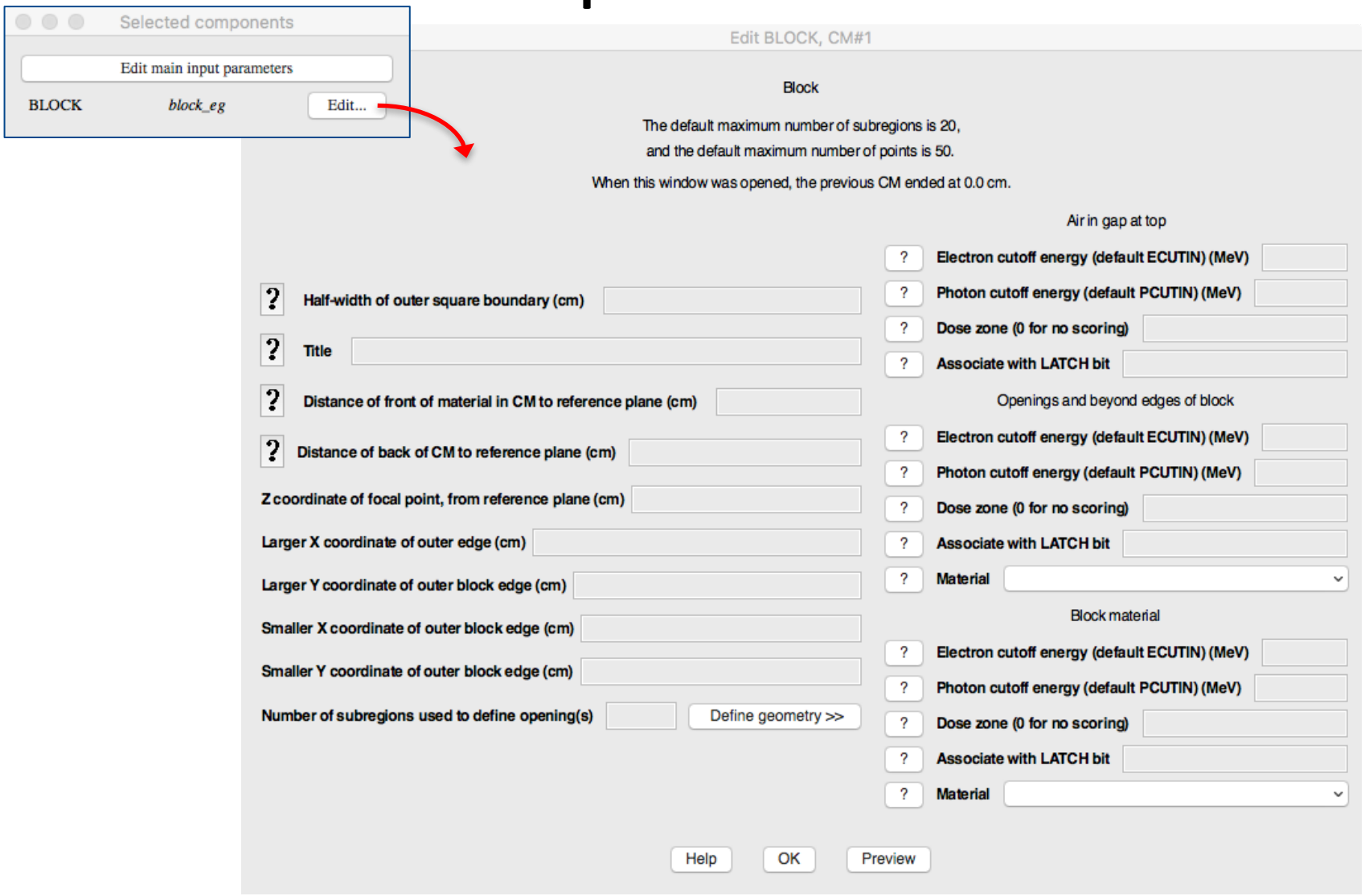
Step 1: Load the accelerator



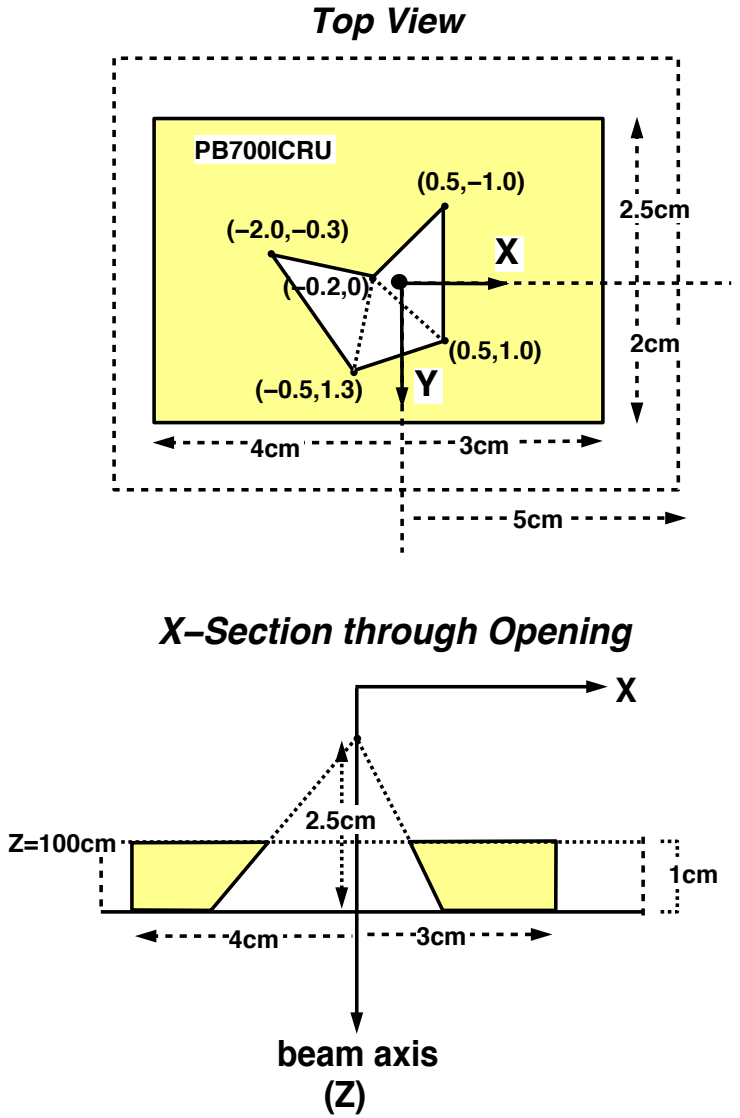
Step 2: Define PEGS data (or go Pegsless)



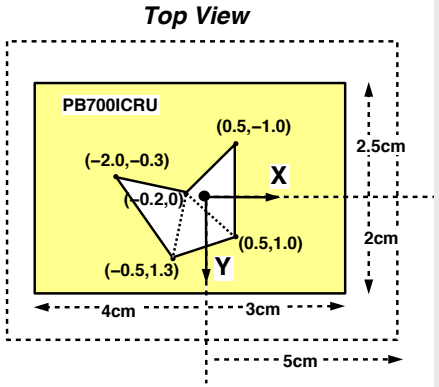
Step 3: Edit CM

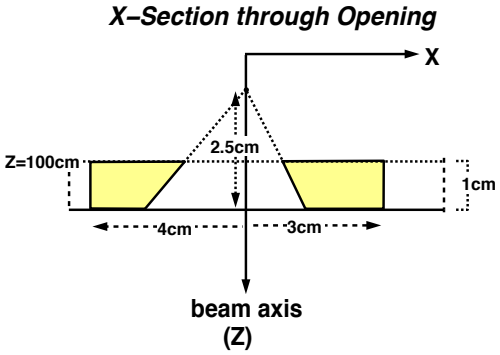


BLOCK e.g.


Top View
PB700ICRU
(0.5,–1.0)
(–2.0,–0.3)
X
(–0.2,0)
(0.5,1.0)
(–0.5,1.3)
Y
2.5cm
2cm
4cm
3cm
5cm
X–Section through Opening
X
2.5cm
Z=100cm
1cm
4cm
3cm
beam axis
(Z)

BLOCK e.g. (cont.)





If left blank default to 0

If left blank default to ECUT, PCUT

Half-width of outer square boundary (cm)	5
Title	Block eg
Distance of front of material in CM to reference plane (cm)	100.0
Distance of back of CM to reference plane (cm)	101.0
Z coordinate of focal point, from reference plane (cm)	98.5
Larger X coordinate of outer edge (cm)	3
Larger Y coordinate of outer block edge (cm)	2
Smaller X coordinate of outer block edge (cm)	-4
Smaller Y coordinate of outer block edge (cm)	-2.5
Number of subregions used to define opening(s)	3

Define geometry >>

Air in gap at top

Electron cutoff energy (default ECUTIN) (MeV)	.7
Photon cutoff energy (default PCUTIN) (MeV)	.01
Dose zone (0 for no scoring)	0
Associate with LATCH bit	0

Openings and beyond edges of block

Electron cutoff energy (default ECUTIN) (MeV)	.7
Photon cutoff energy (default PCUTIN) (MeV)	.01
Dose zone (0 for no scoring)	0
Associate with LATCH bit	0
Material	AIR700ICRU

Block material

Electron cutoff energy (default ECUTIN) (MeV)	.7
Photon cutoff energy (default PCUTIN) (MeV)	.01
Dose zone (0 for no scoring)	1
Associate with LATCH bit	1
Material	PB700ICRU

Help OK Preview

No interior angle can be > 180°

Menu with all media in `700icru.pegs4dat`

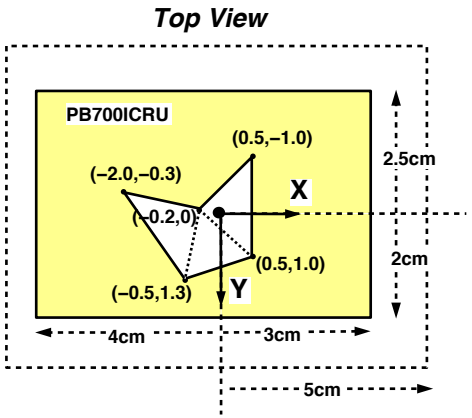
BLOCK e.g. (cont.)

Dose deposited in the block matl. will be included in dose zone 1

Bit region:

- **Particles passing through (`LATCH` by passage) or interacting in (`LATCH` by interaction) block matl. will have `LATCH` bit 1 set—so will all their 2nds**
- **2nd particles created in block matl. will store the number, 1, in bits 24-28 of their `LATCH`**
- **If left 0 (or blank) will be assigned bit region 23**

BLOCK e.g. (cont.)



Smaller Y coordinate of outer block edge (cm) -2.5

Number of subregions used to define opening(s) 3 Define geometry >>

Define subregions

Number of points defining subregion 1 3 Define points >>

Number of points defining subregion 2 3 Define points >>

Number of points defining subregion 3 3 Define points >>

Help OK

Define subregion 1

Note that all internal angles must be less that 180 degrees.

Point	x	y
1	-2	-0.3
2	-0.2	0
3	-0.5	1.3

Define subregion 2

Note that all internal angles must be less that 180 degrees.

Point	x	y
1	-0.5	1.3
2	-0.2	0
3	0.5	1

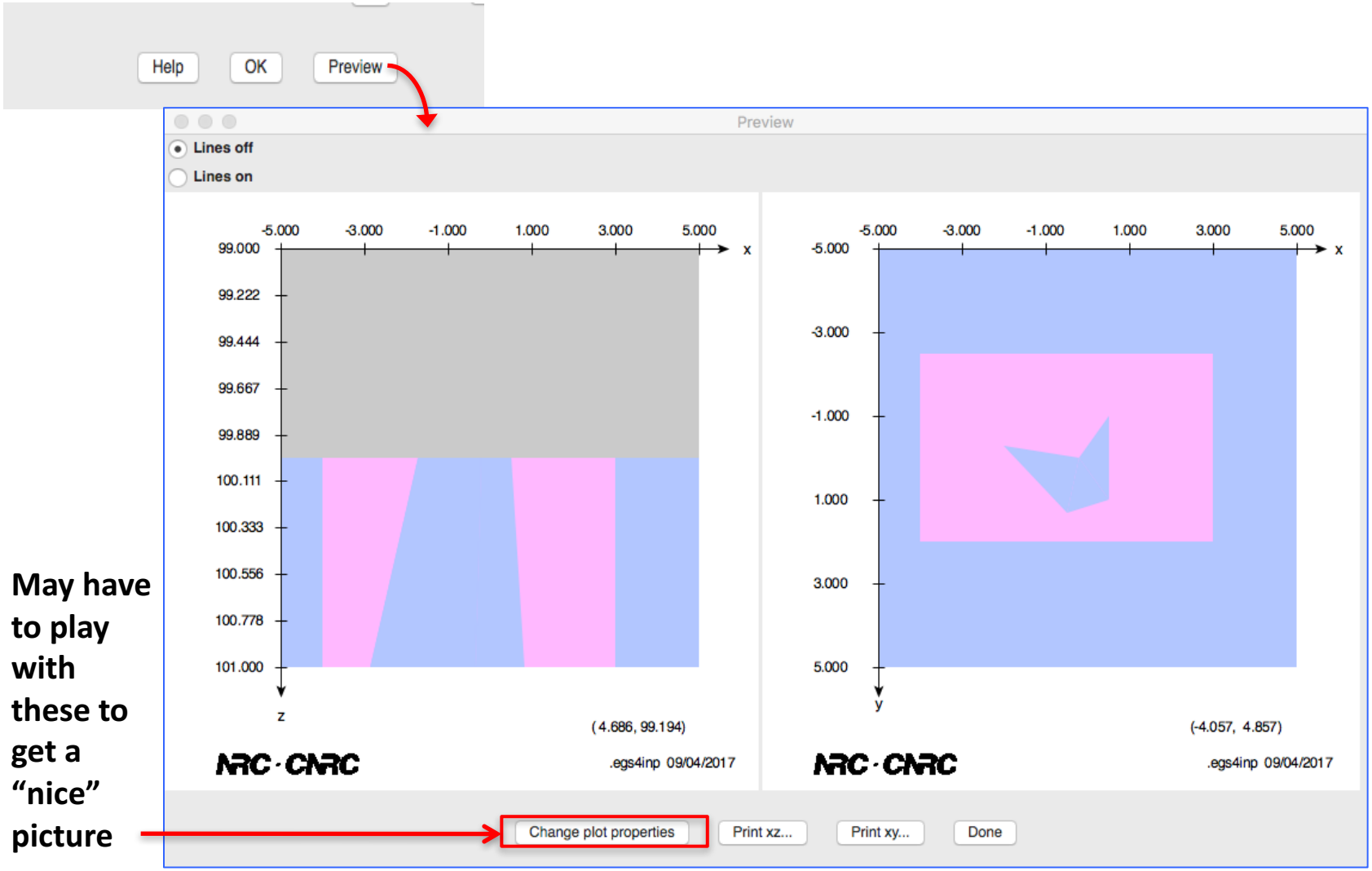
Define subregion 3

Note that all internal angles must be less that 180 degrees.

Point	x	y
1	-0.2	0
2	0.5	-1
3	0.5	1

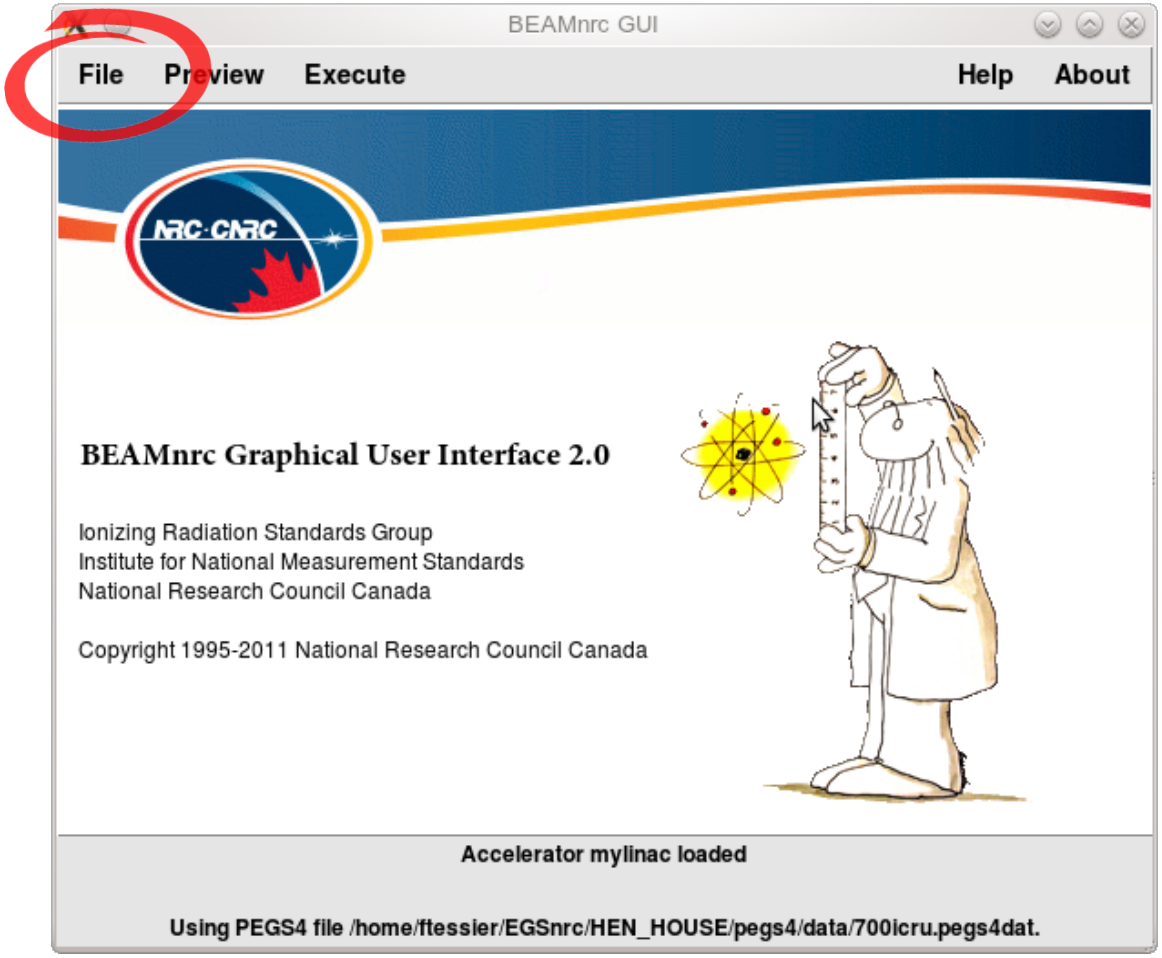
OK

BLOCK e.g. (cont.)

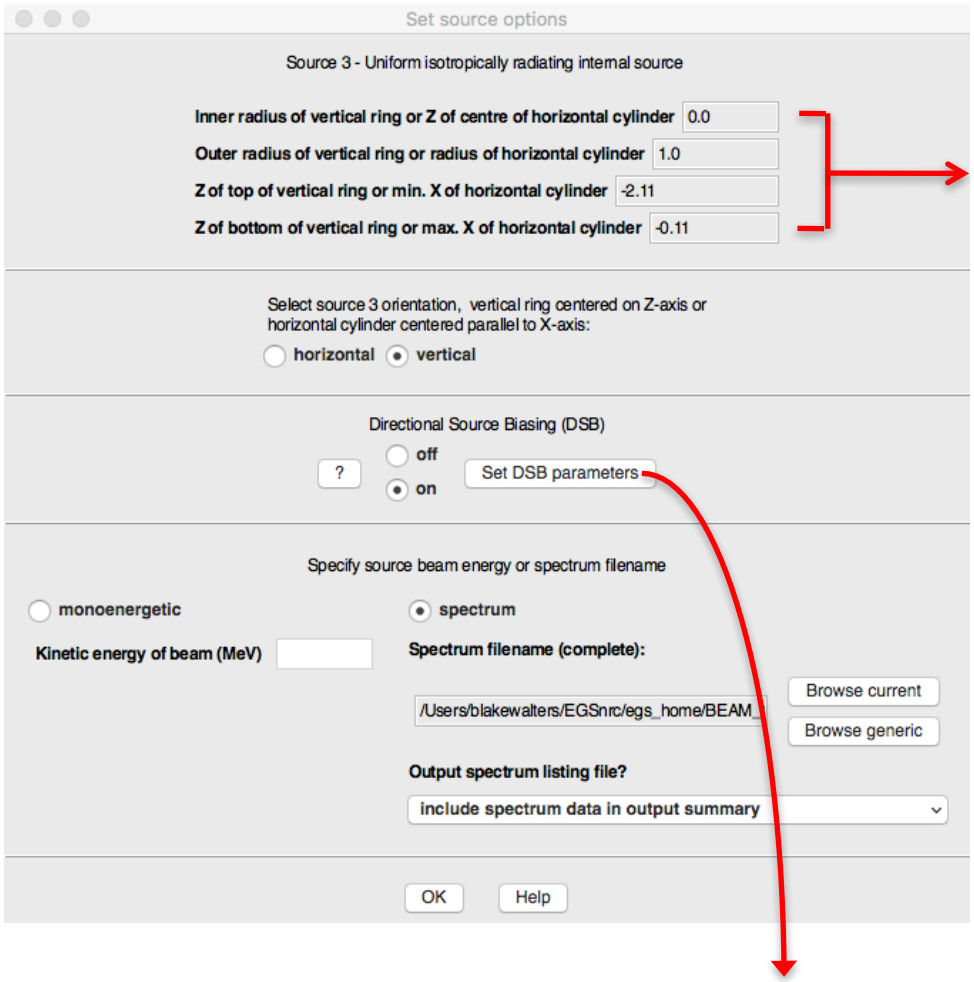


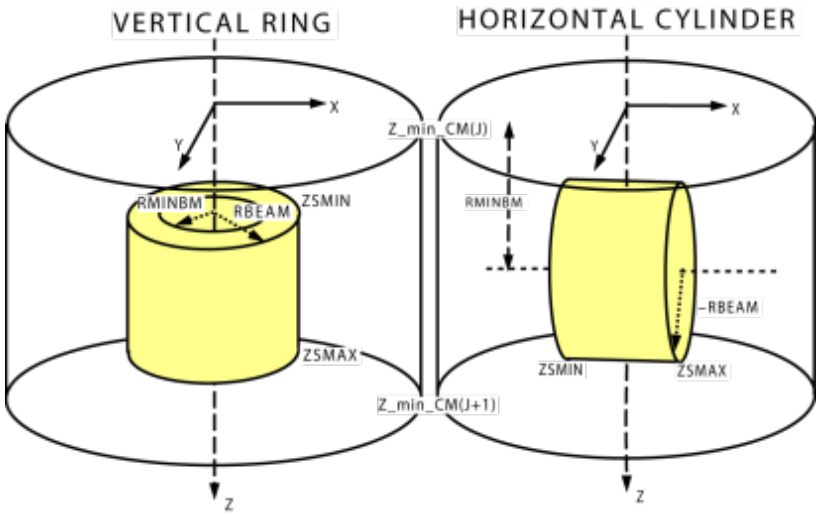
May have to play with these to get a "nice" picture

Don’t forget to save your input file!



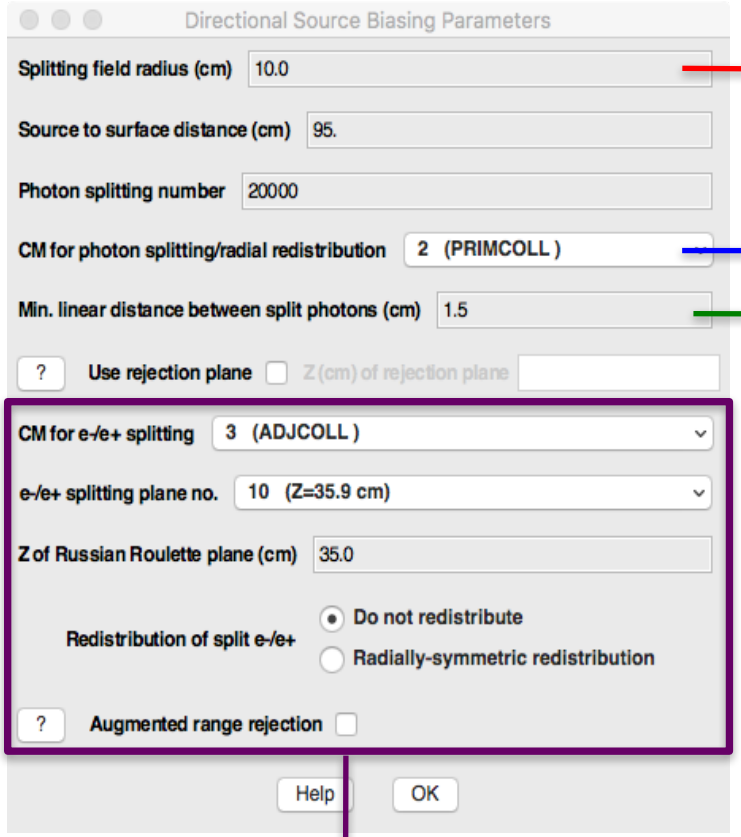
Isotropically radiating source (ISOURC=3)





- **Source volume must be completely contained within CMs that can handle internal sources: FLATFILT, SIDETUBE, CONESTAK, SLABS**
- **It's up to you to contain the source within a volume of the appropriate medium (e.g. CO700ICRU)**

Directional source biasing (DSB)



e- splitting scheme to recover contaminant charged particles is the same as that used in DBS