

**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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National Research Council Canada



Government
of Canada

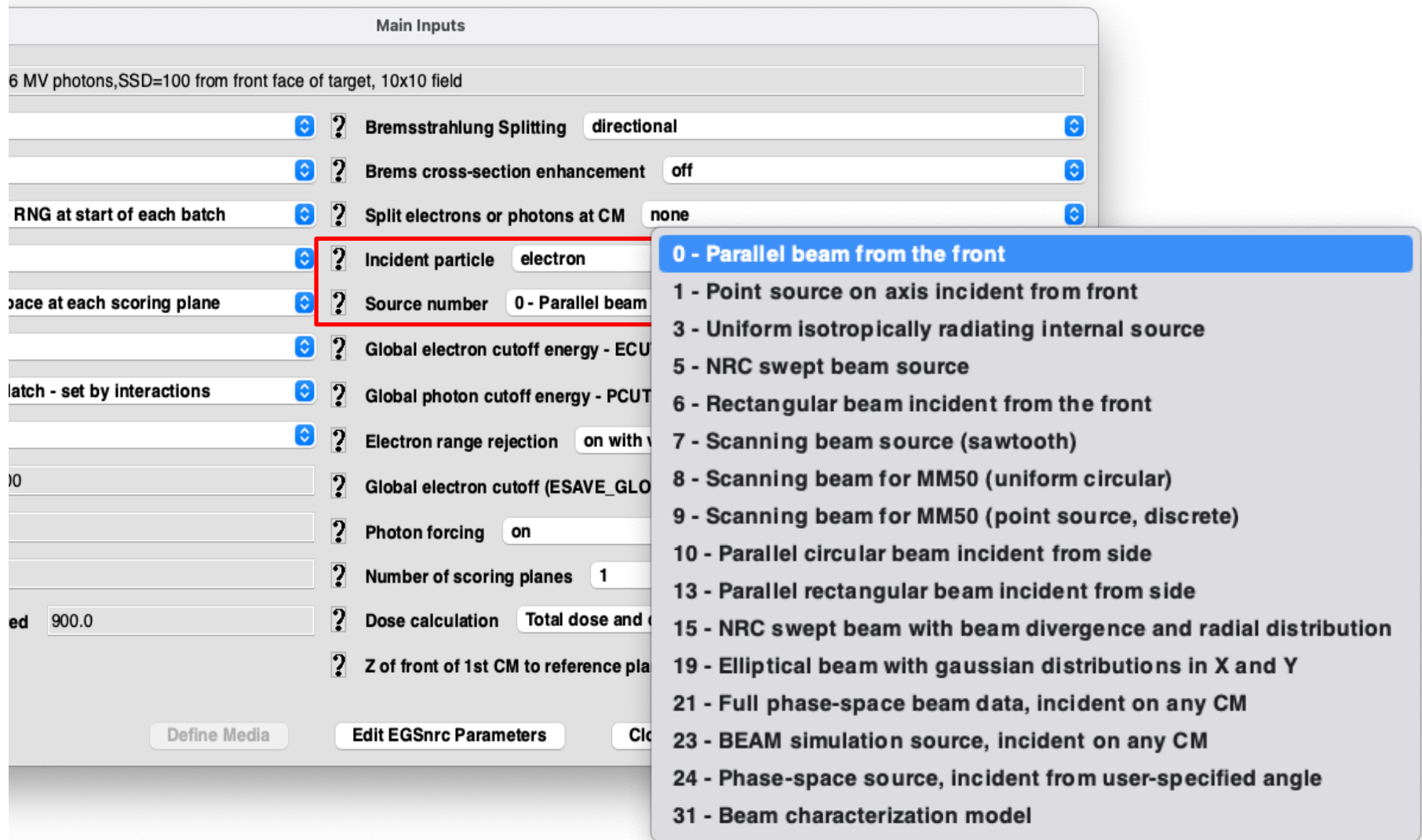
Gouvernement
du Canada



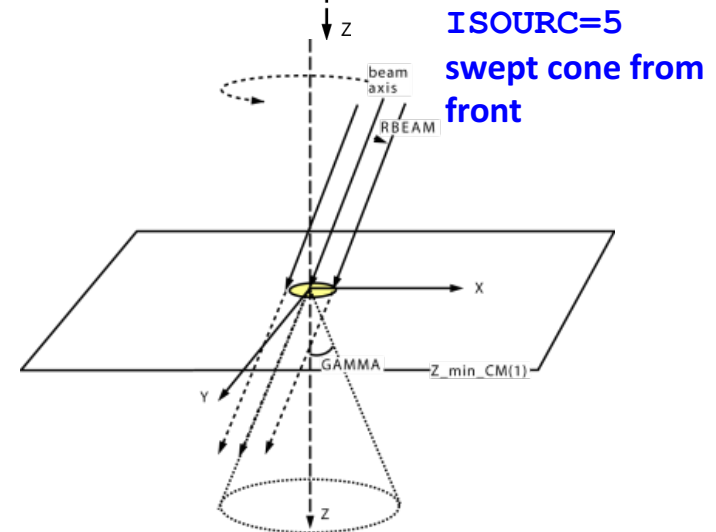
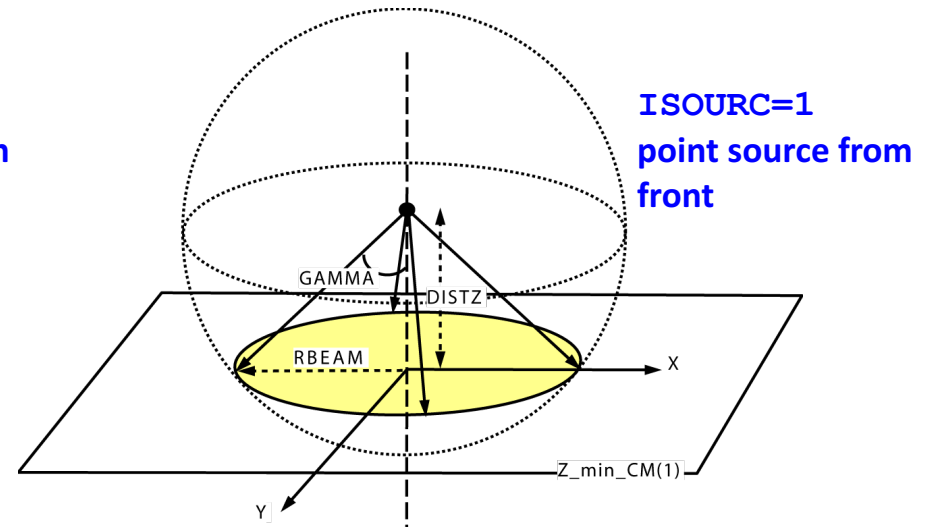
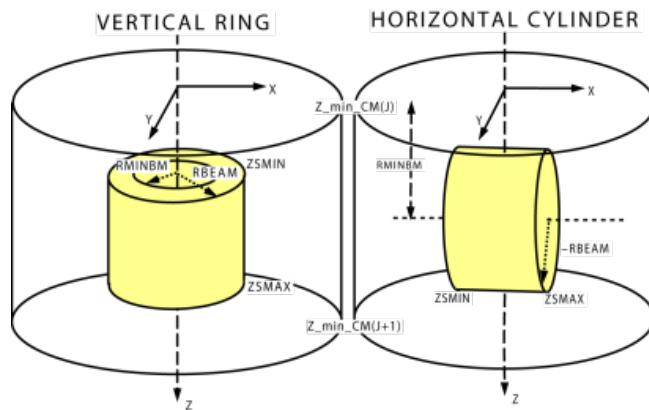
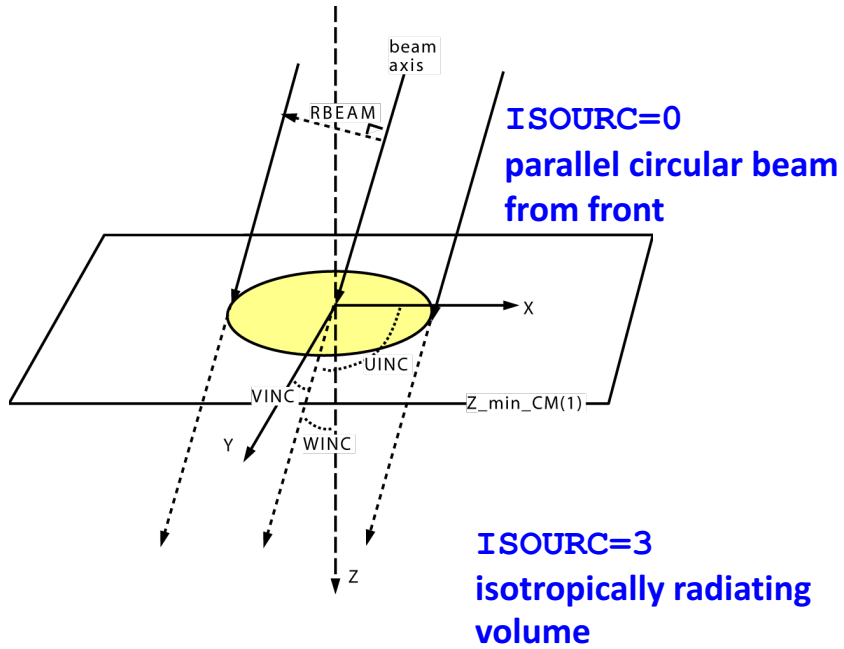
Sources

2011/12/16

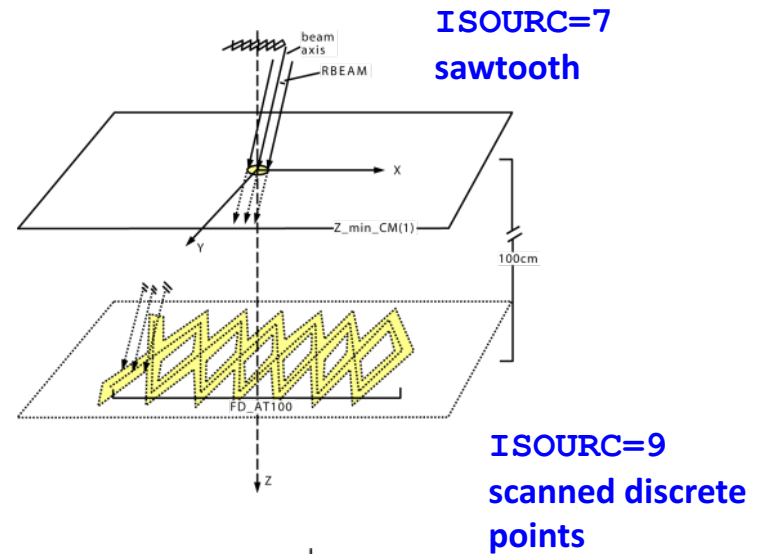
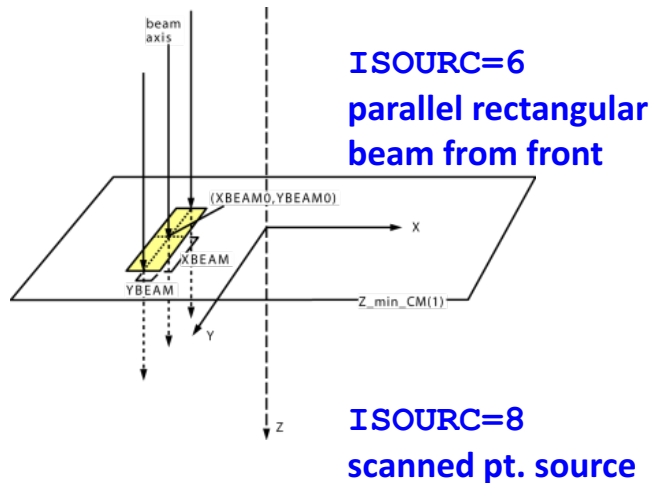
Main BEAMnrc GUI Window



Primary source collection

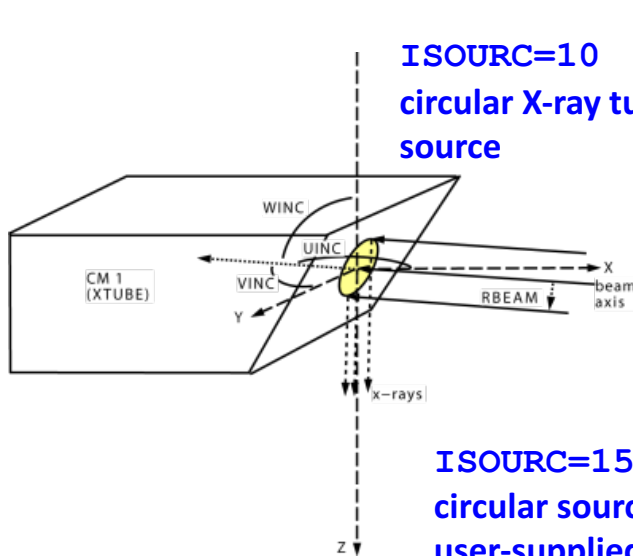


Primary source collection (cont.)

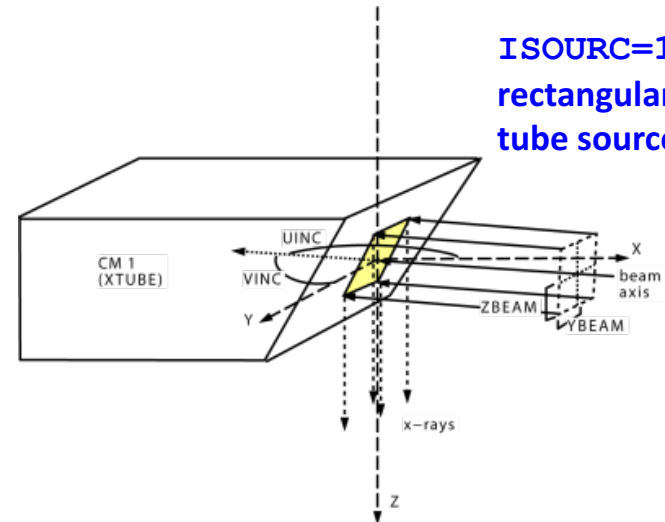


Primary source collection (cont.)

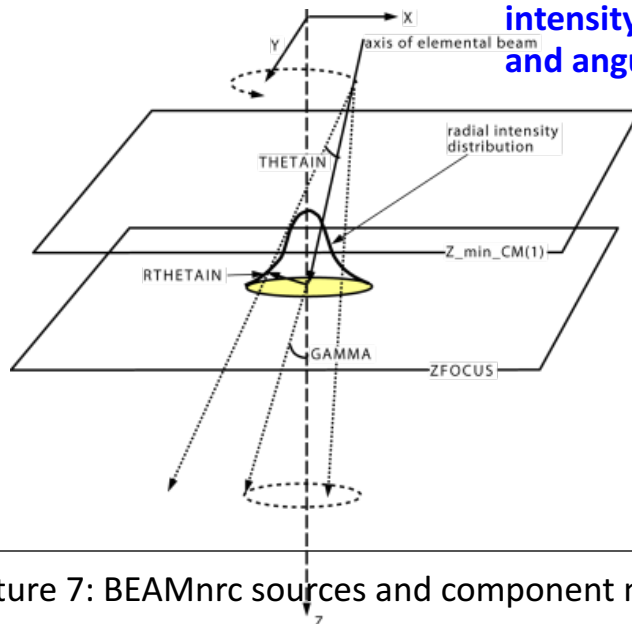
ISOUC=10
circular X-ray tube
source



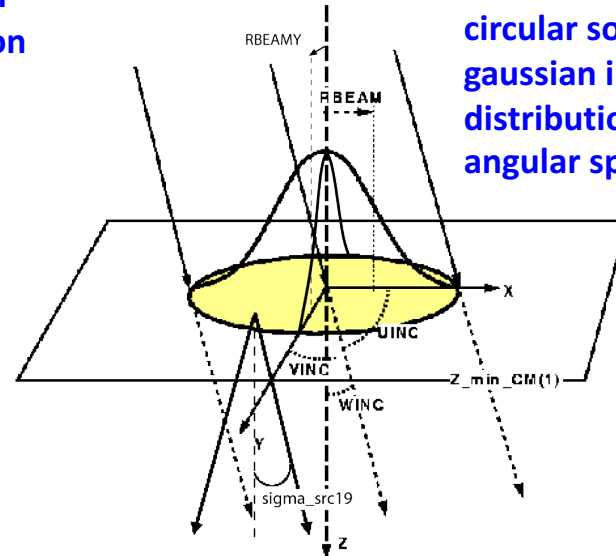
ISOUC=13
rectangular X-ray
tube source



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

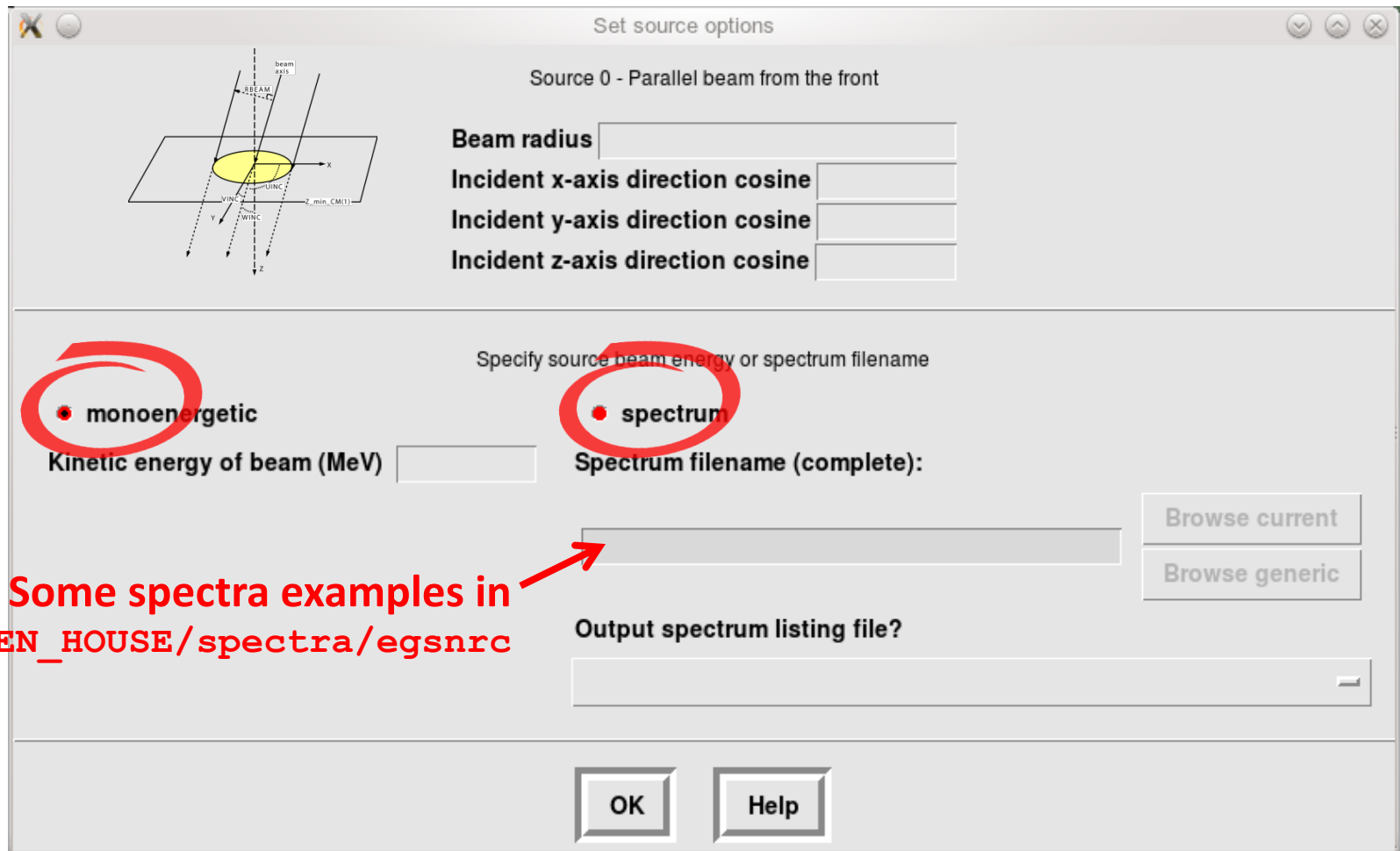


ISOUC=19
circular source with
gaussian intensity
distribution &
angular spread



Primary sources

- Can be monoenergetic or have an energy spectrum



Set source options

Source 0 - Parallel beam from the front

Beam radius

Incident x-axis direction cosine

Incident y-axis direction cosine

Incident z-axis direction cosine

Specify source beam energy or spectrum filename

☒ monoenergetic

Kinetic energy of beam (MeV)

☒ spectrum

Spectrum filename (complete):

Output spectrum listing file?

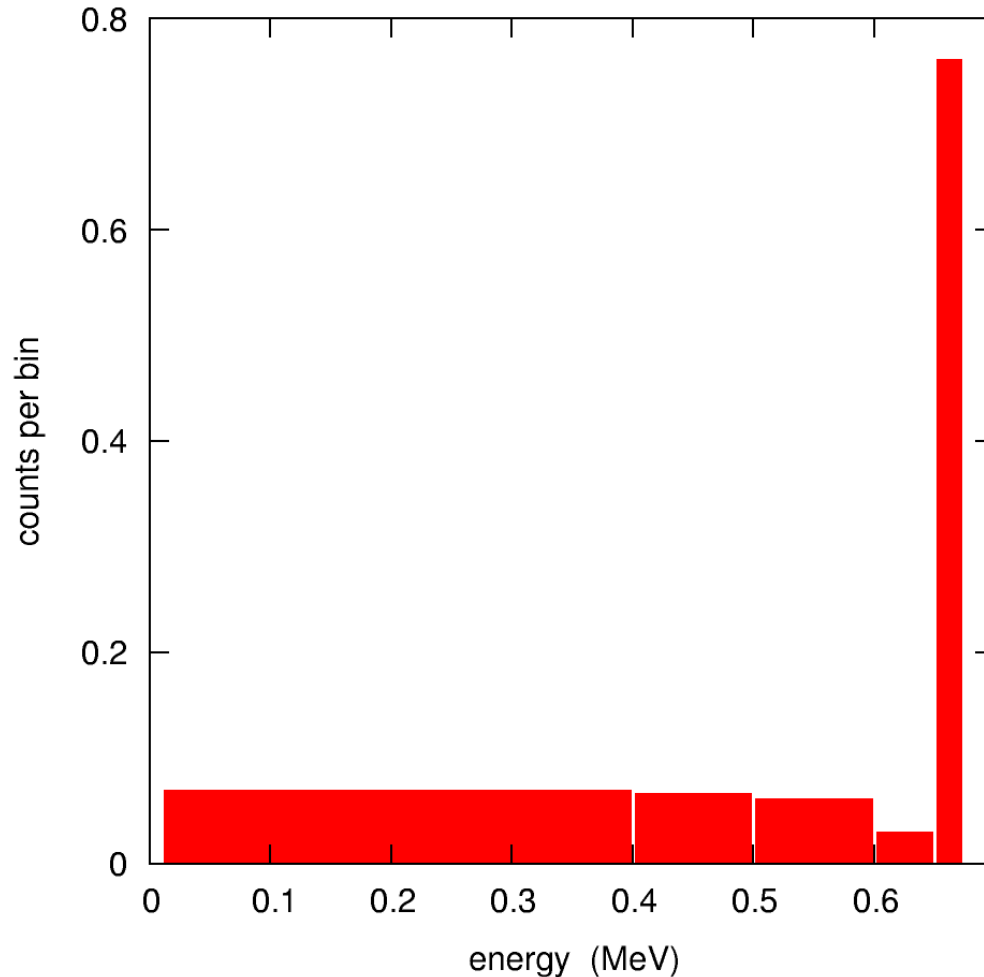
Some spectra examples in `$HEN_HOUSE/spectra/egsnrc`

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)

Set source options

Source 21 - Full phase-space beam data, incident on any CM

CM at which particles start 1

No. of times to recycle particles (NRCYCL) 0

No. of parallel jobs (IPARALLEL)

Parallel job no. (PARNUM)

☒ DBS used to generate source

DBS splitting field radius (cm) 7.5

SSD of splitting field (cm) 100.0

Z where source scored (cm) 22.5

Phase space information file (complete):

/Users/blakewalters/EGSnrc/egs_home/BEAM_EX16MVp/E

Browse current

Browse generic

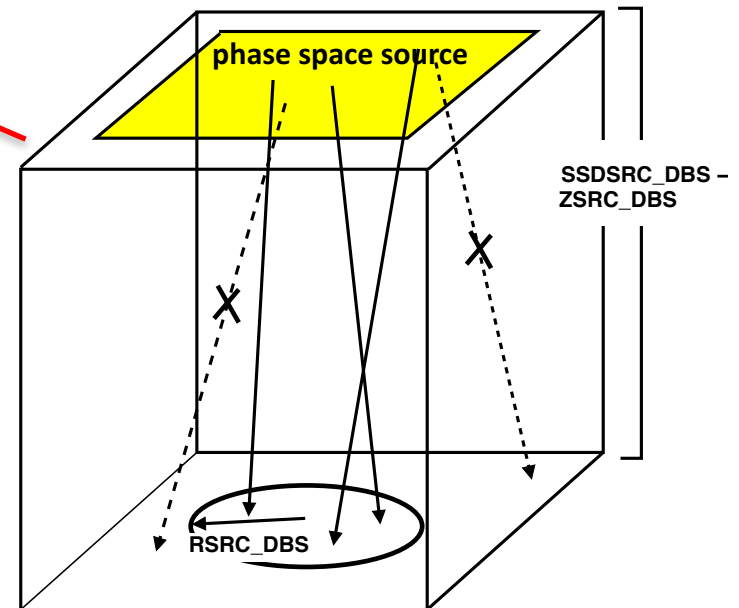
OK Help

If set to 0 (blank)

$NRCYCL = NCASE / NPHSP$

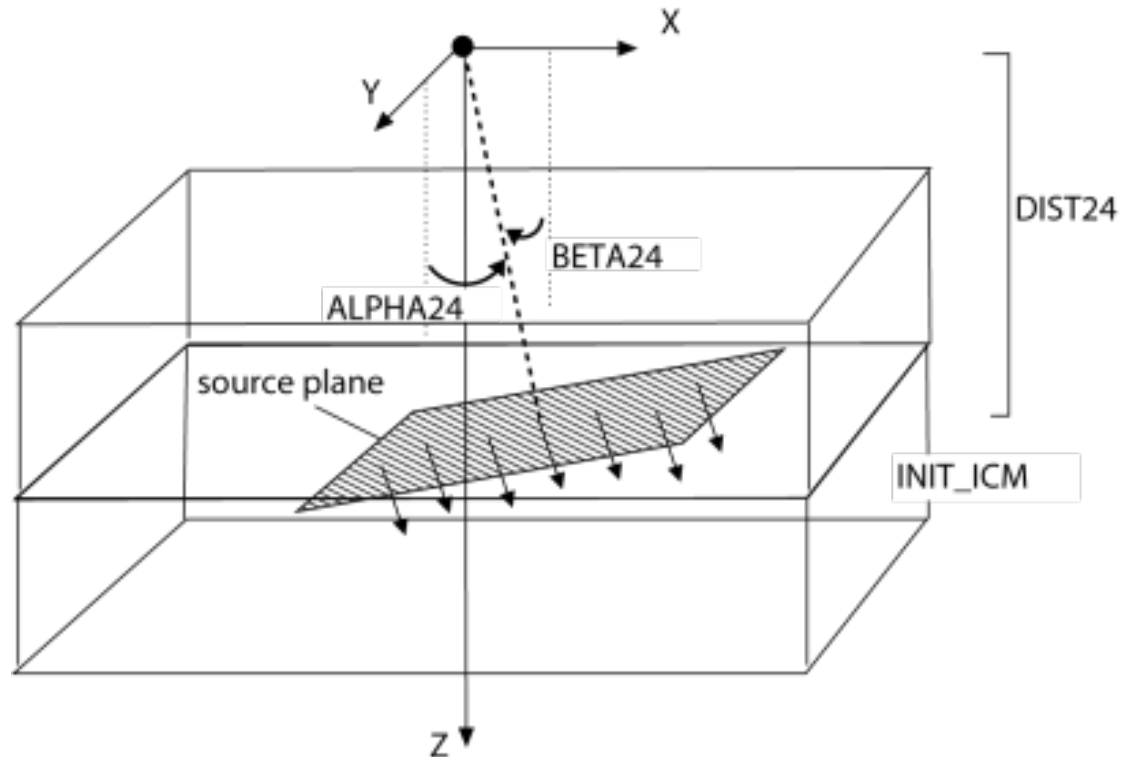
No longer used

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)

Set source options

Source 23 - BEAM simulation source, incident on any CM

CM at which particles start 1

angle of rotation wrt X-axis (degrees) 0

angle of rotation wrt Y-axis (degrees) 0

distance of point of rotation above starting CM (cm) 0

☒ Reject fat photons from DBS

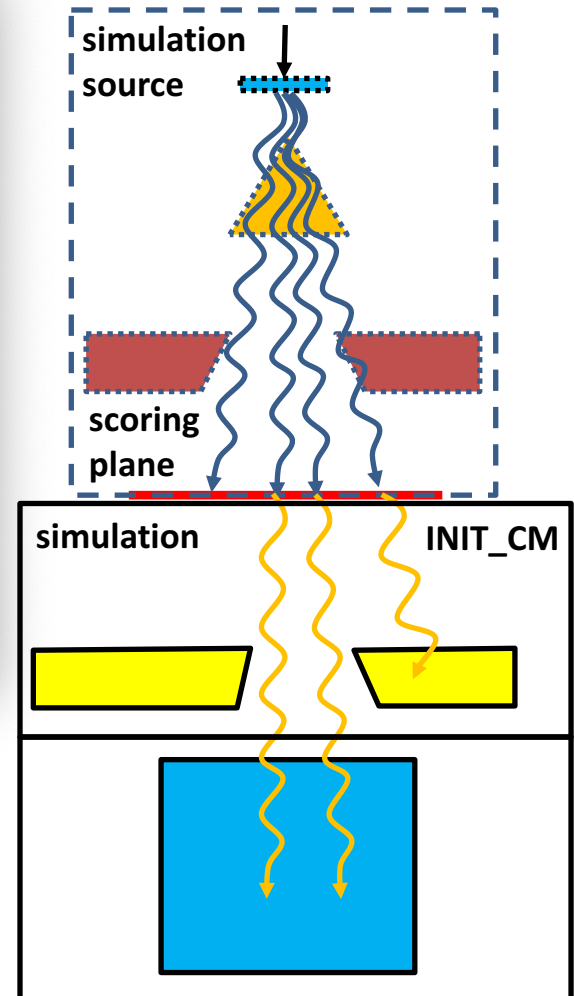
BEAM simulation: BEAM_EX16MVp

input file (no ext.): EX16MVp

pegs data (no ext.): 700icru

Compiled as shared library

Must exist in source's
BEAM_accelname
directory



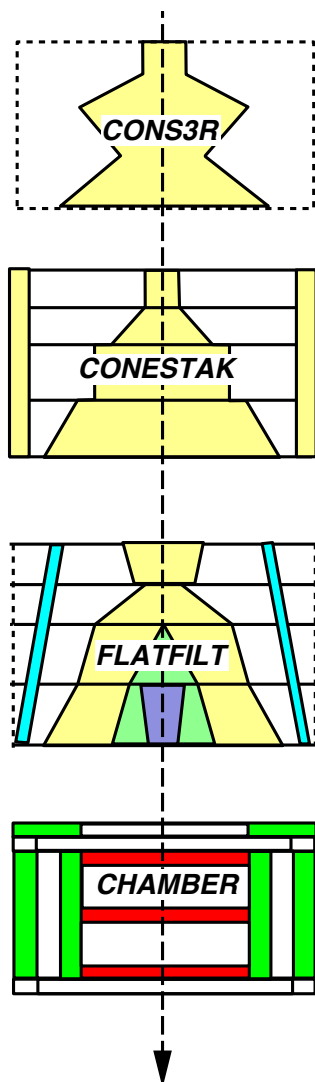
Component Modules

What are Component Modules (**CMs**)?

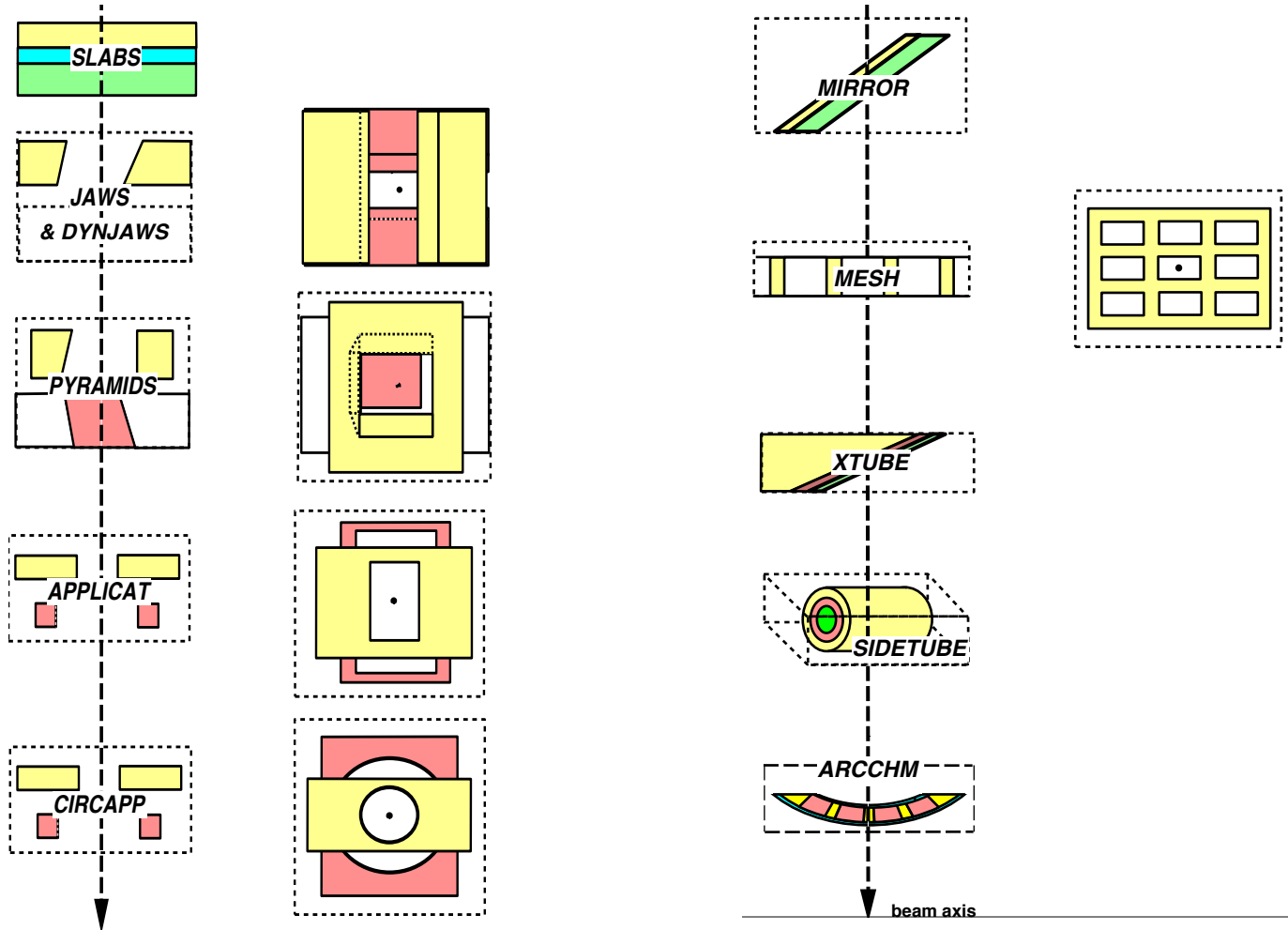


- Blocks of MORTRAN (sorry) code optimized for simulating typical accelerator components
- Stacked on top of one another to create an accelerator
- Outer boundaries always centred on beam (Z) axis

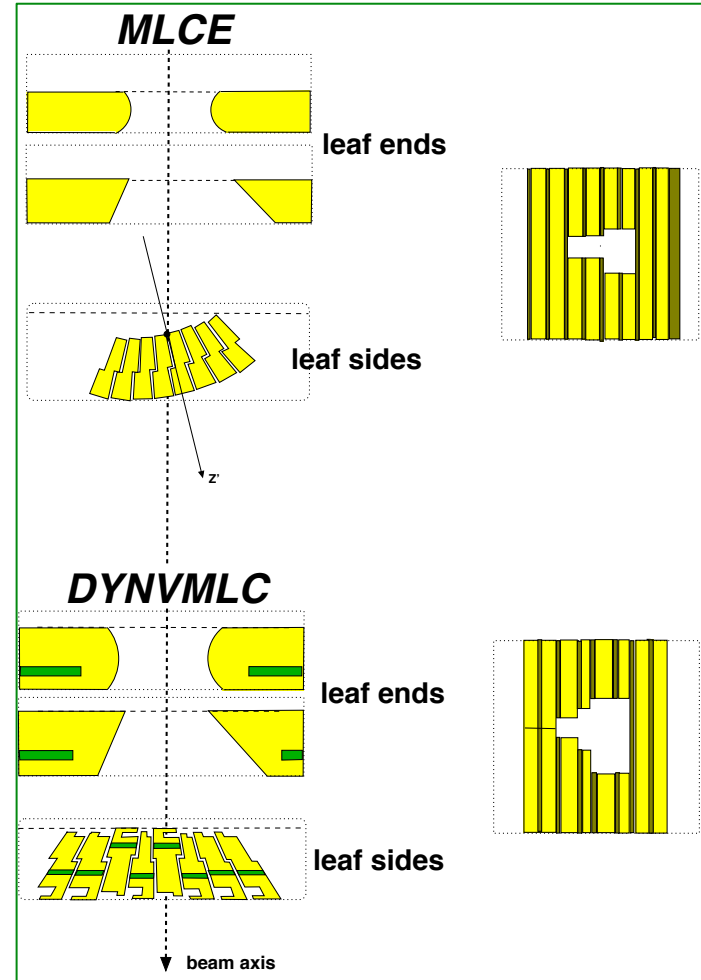
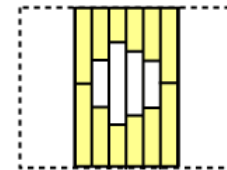
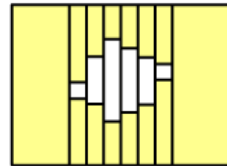
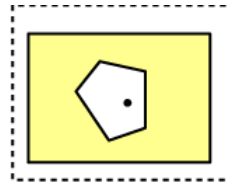
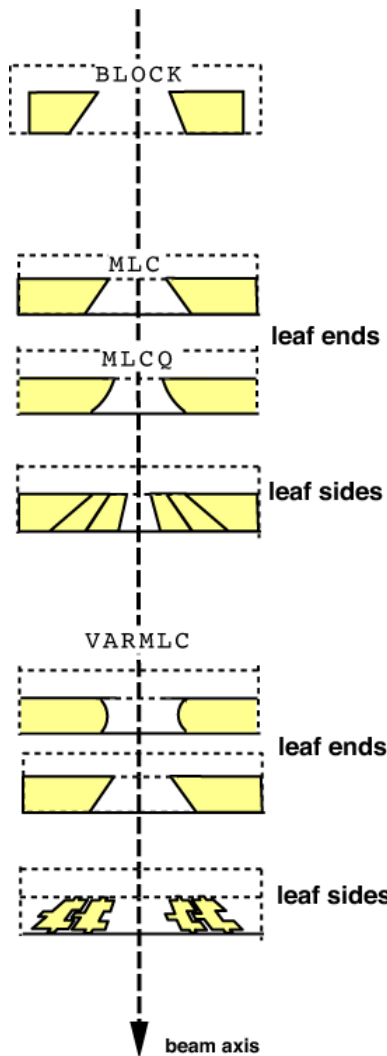
Cylindrical component modules



Square component modules



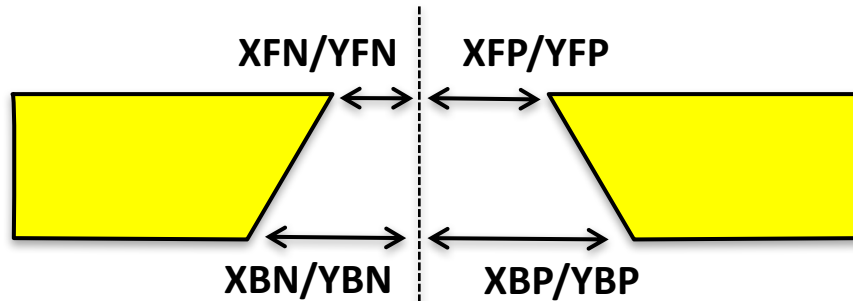
Multi-leaf collimators



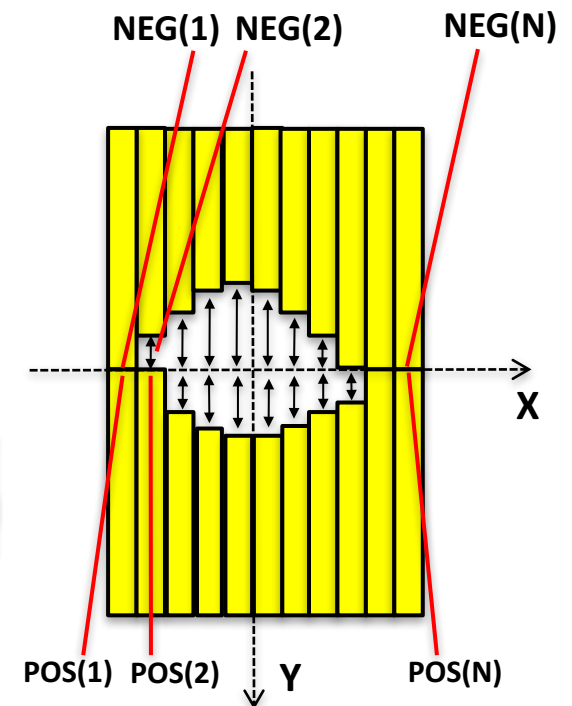
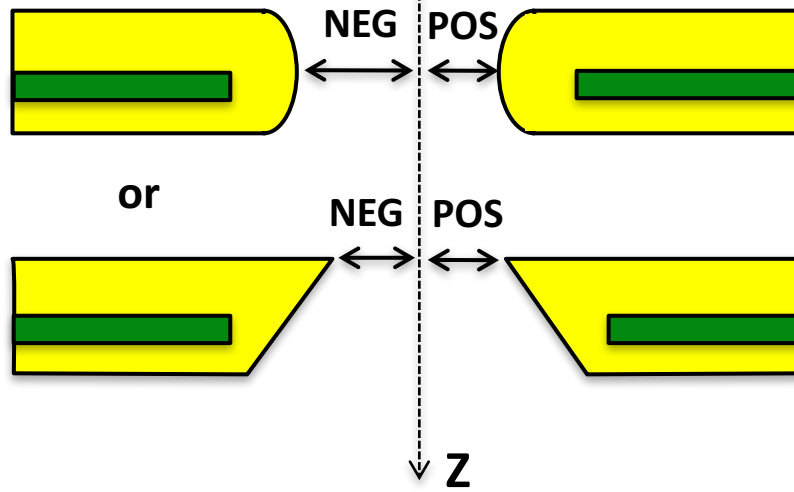
Dynamic component modules

“time” varying opening coordinates

DYNJAWS



DYNVMLC



Dynamic component modules (cont.)

GUI inputs

Edit DYNJAWS, CM#1

DYNJAWS

The default maximum number of paired bars or jaws is 12.

When this window was opened, the previous CM ended at 0.0 cm.

? Half-width of outer square boundary (cm) 10.0

? Title test of dynjaws

Select field type:

Number of paired bars 2

☐ Static

☒ Dynamic

☐ Step-and-shoot

Define jaw orientation/media

File containing jaw opening data: /Users/blakewalters/EGS Browse

Openings:

? Electron cutoff energy (default ECUTIN) (MeV) 0.7

? Photon cutoff energy (default PCUTIN) (MeV) 0.01

? Dose zone (0 for no scoring) 0

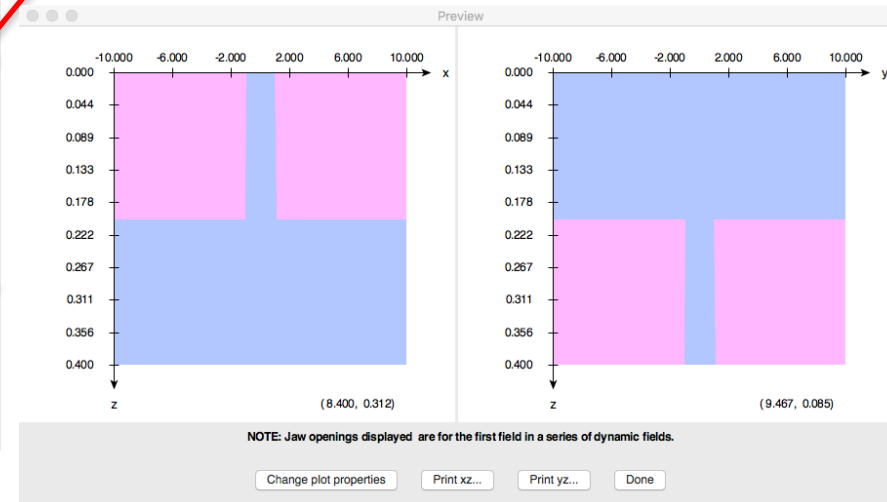
? Associate with LATCH bit 0

Help OK Preview

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)	
field 1	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	
field 2	0.001, 0.2, 1, 1.1, -1, -1.1	
	0.201, 0.2, 2, 2.1, -2, -2.1	
	0.66	
field 3	0.001, 0.2, 2, 2.1, -2, -2.1	
	0.201, 0.2, 1, 1.1, -1, -1.1	
	1.0	
field 4	0.001, 0.2, 2, 2.1, -2, -2.1	
	0.201, 0.2, 2, 2.1, -2, -2.1	

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.)

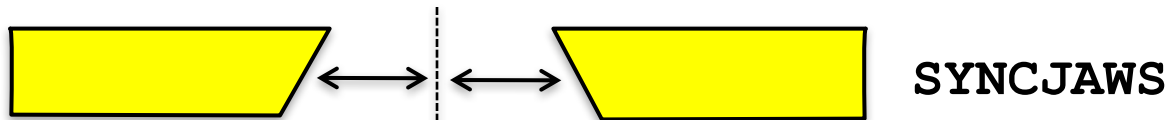
Field selection

- random fractional monitor unit (MU) $\in [0,1)$ selected at the beginning of each primary history
- for field, i , where $\text{INDEX}(i-1) < \text{MU} \leq \text{INDEX}(i)$, dimension parameter, P ($P \equiv \text{xfp}, \text{xbp}, \dots$), is chosen using:

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

Synchronized component modules

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

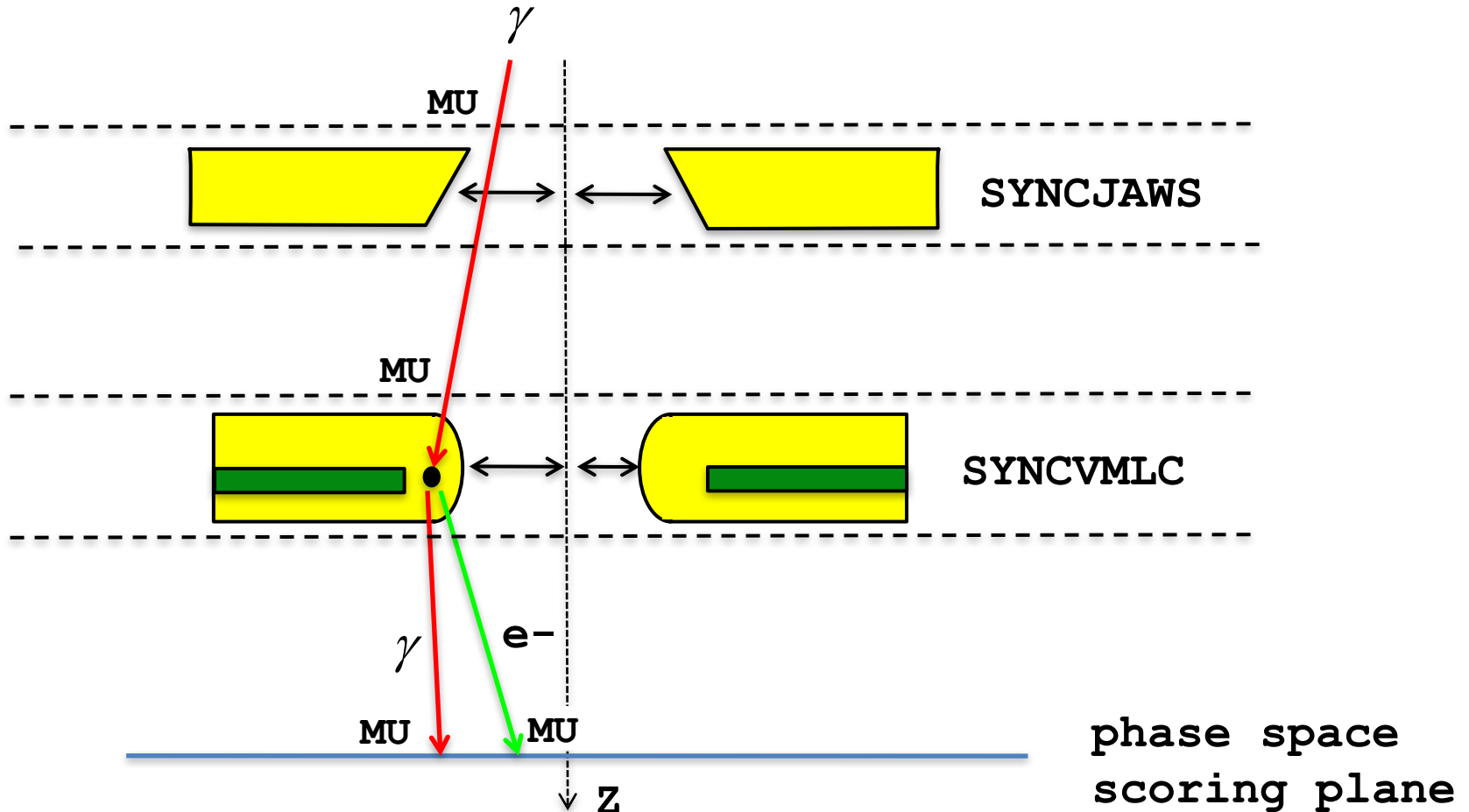


mlc type	leaf ends	leaf x-section (define once)
SYNCMLCE		
SYNCSVMLC	or 	
SYNCHDMLC		

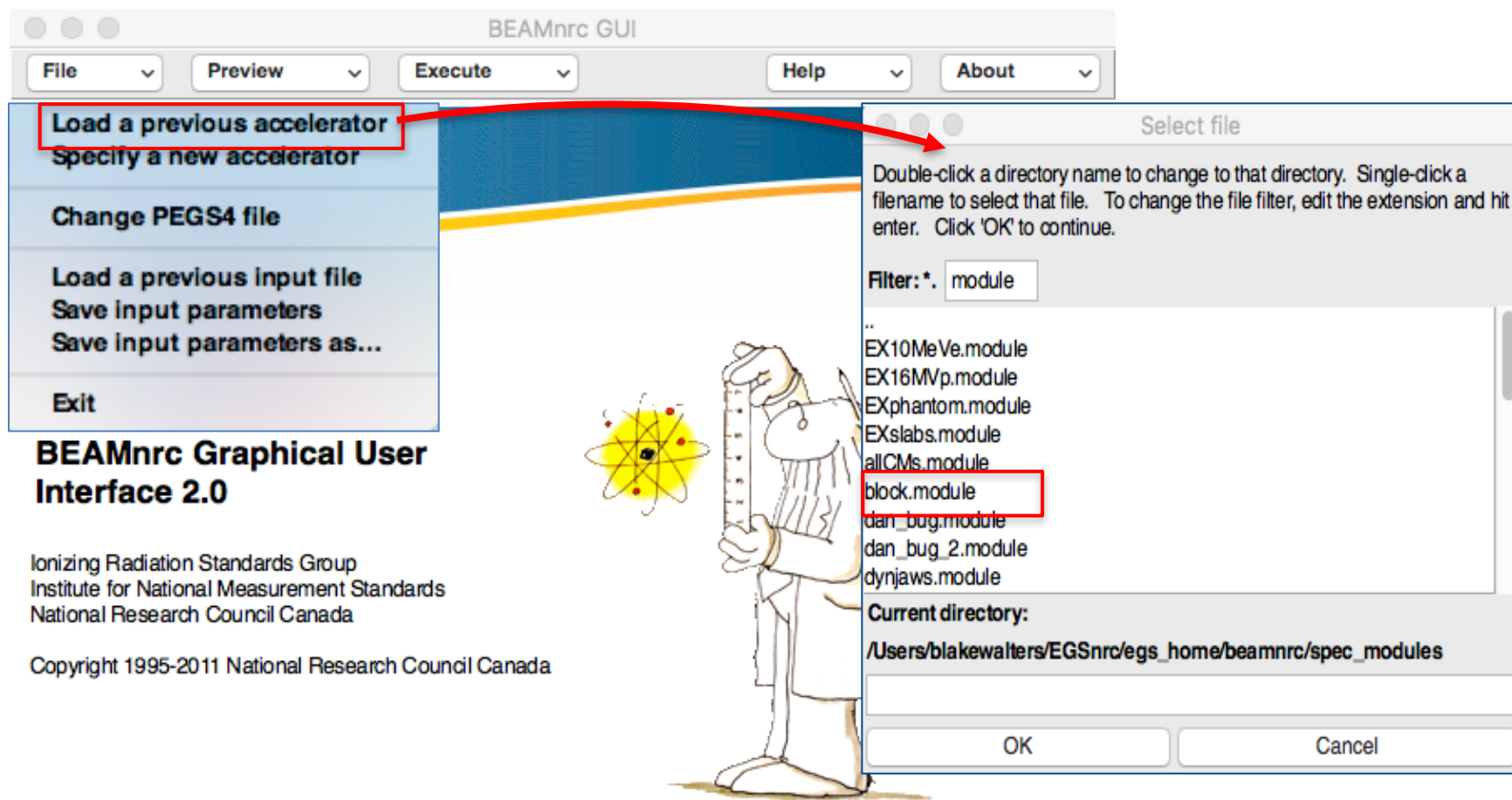
↓ Z

Synchronized component modules (cont.)

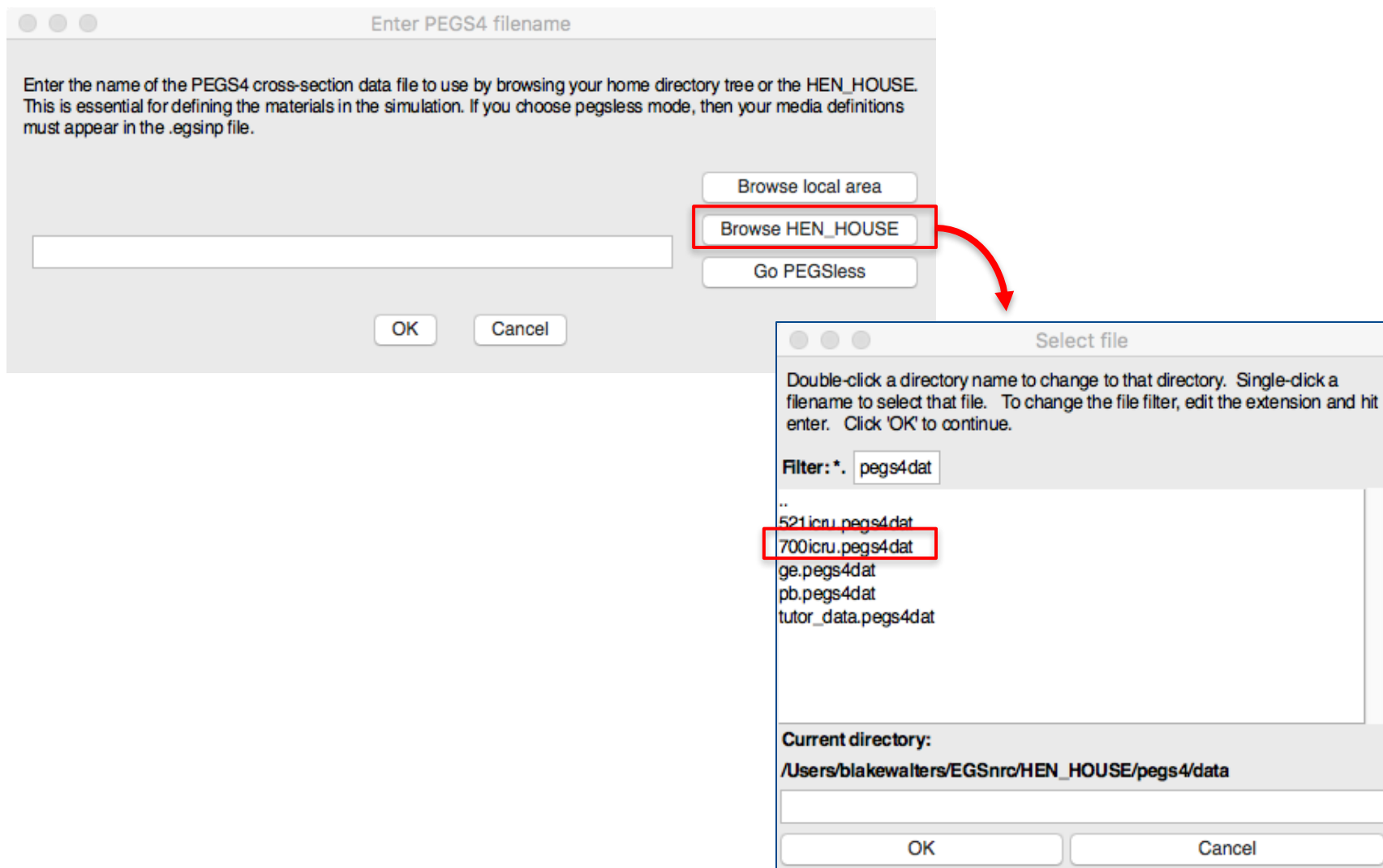
- For each particle (and its descendants) the same value of MU is used for all synchronized CMs



Step 1: Load the accelerator



Step 2: Define PEGS data (or go Pegsless)



Step 3: Edit CM

Selected components

Edit main input parameters

BLOCK *block_eg* Edit...

Edit BLOCK, CM#1

Block

The default maximum number of subregions is 20,
and the default maximum number of points is 50.

When this window was opened, the previous CM ended at 0.0 cm.

Air in gap at top

? Half-width of outer square boundary (cm)

? Title

? Distance of front of material in CM to reference plane (cm)

? Distance of back of CM to reference plane (cm)

Z coordinate of focal point, from reference plane (cm)

Larger X coordinate of outer edge (cm)

Larger Y coordinate of outer block edge (cm)

Smaller X coordinate of outer block edge (cm)

Smaller Y coordinate of outer block edge (cm)

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

? Electron cutoff energy (default ECUTIN) (MeV)

? Photon cutoff energy (default PCUTIN) (MeV)

? Dose zone (0 for no scoring)

? Associate with LATCH bit

Openings and beyond edges of block

? Electron cutoff energy (default ECUTIN) (MeV)

? Photon cutoff energy (default PCUTIN) (MeV)

? Dose zone (0 for no scoring)

? Associate with LATCH bit

? Material

Block material

? Electron cutoff energy (default ECUTIN) (MeV)

? Photon cutoff energy (default PCUTIN) (MeV)

? Dose zone (0 for no scoring)

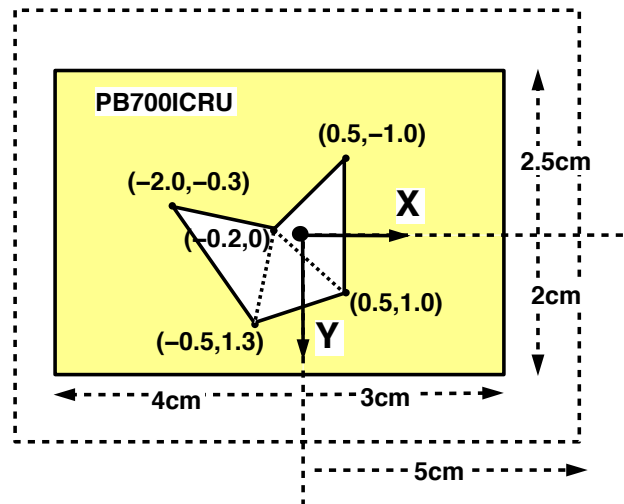
? Associate with LATCH bit

? Material

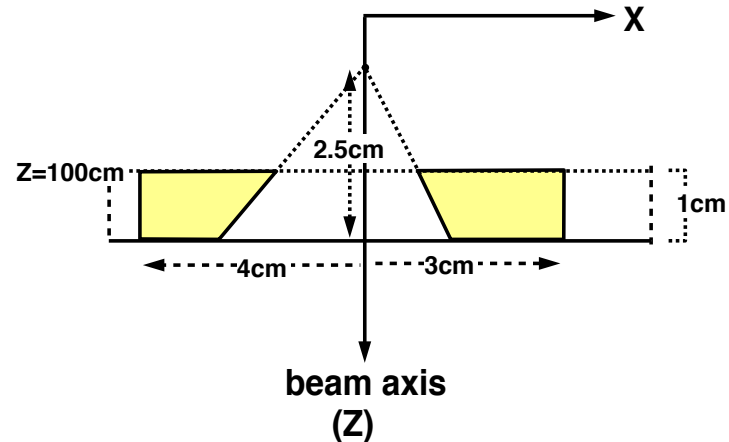
Help OK Preview

BLOCK e.g.

Top View

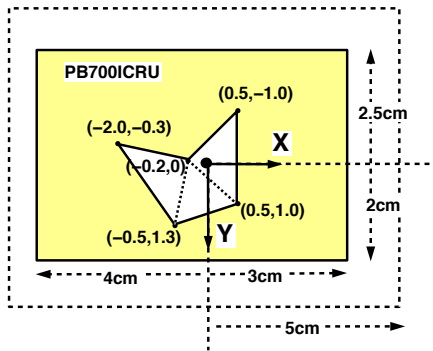


X-Section through Opening

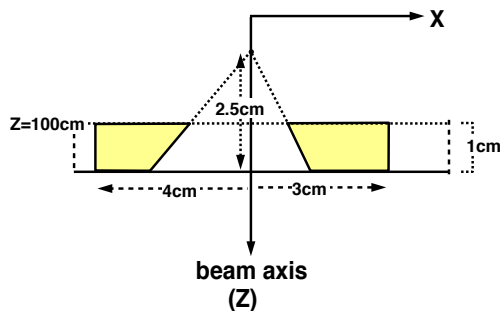


BLOCK e.g. (cont.)

Top View



X-Section through Opening



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

? 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 >>

Help OK Preview

No interior angle can be > 180°

If left blank default to 0

If left blank default to ECUT, PCUT

Menu with all media in 700icru. pegs4dat

BLOCK e.g. (cont.)

The screenshot shows the BLOCK configuration window with the following settings:

- 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

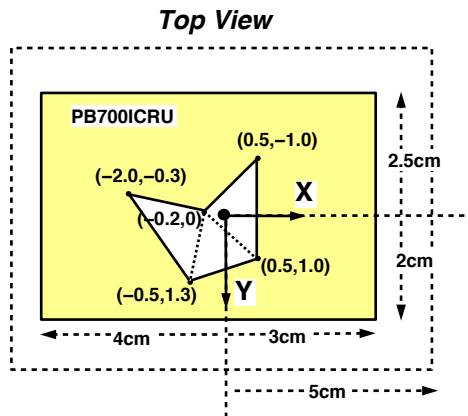
On the left side of the window, there are input fields for geometry: 'ry (cm)' with value 5, 'to reference plane (cm)' with value 100.0, 'e plane (cm)' with value 101.0, 'e plane (cm)' with value 98.5, '3', '(cm)' with value 2, '(cm)' with value -4, '(cm)' with value -2.5, and 'ening(s)' with value 3. A 'Define geometry >>' button is located below these fields. At the bottom of the window are 'Help', 'OK', and 'Preview' buttons.

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)

Number of subregions used to define opening(s)

Define subregions

Number of points defining subregion 1

Number of points defining subregion 2

Number of points defining subregion 3

Define subregion 1

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

Point	x	y
1	<input type="text" value="-2"/>	<input type="text" value="-0.3"/>
2	<input type="text" value="-0.2"/>	<input type="text" value="0"/>
3	<input type="text" value="-0.5"/>	<input type="text" value="1.3"/>

Define subregion 2

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

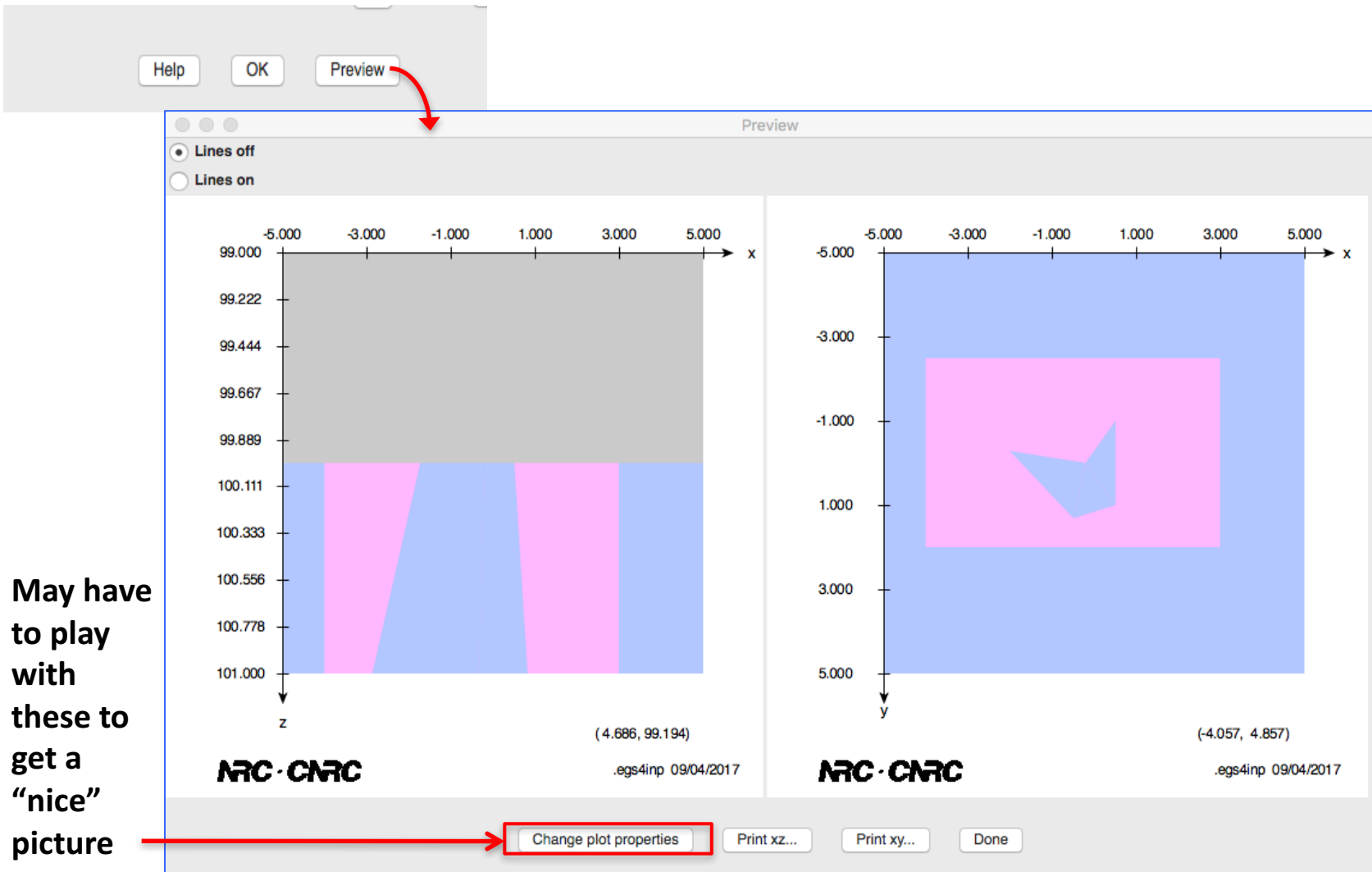
Point	x	y
1	<input type="text" value="-0.5"/>	<input type="text" value="1.3"/>
2	<input type="text" value="-0.2"/>	<input type="text" value="0"/>
3	<input type="text" value="0.5"/>	<input type="text" value="1"/>

Define subregion 3

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

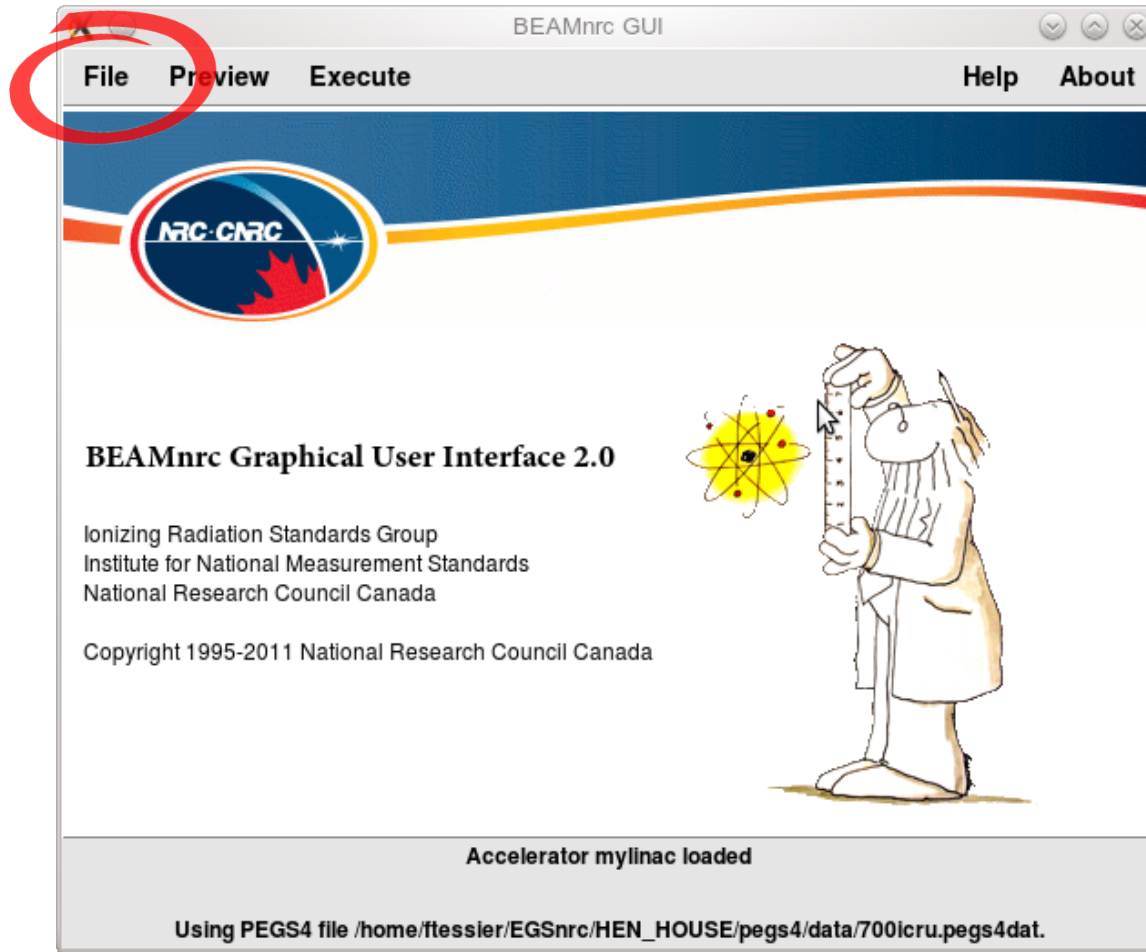
Point	x	y
1	<input type="text" value="-0.2"/>	<input type="text" value="0"/>
2	<input type="text" value="0.5"/>	<input type="text" value="-1"/>
3	<input type="text" value="0.5"/>	<input type="text" value="1"/>

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)

Set source options

Source 3 - Uniform isotropically radiating internal source

Inner radius of vertical ring or Z of centre of horizontal cylinder 0.0

Outer radius of vertical ring or radius of horizontal cylinder 1.0

Z of top of vertical ring or min. X of horizontal cylinder -2.11

Z of bottom of vertical ring or max. X of horizontal cylinder -0.11

Select source 3 orientation, vertical ring centered on Z-axis or horizontal cylinder centered parallel to X-axis:

☐ horizontal ☒ vertical

Directional Source Biasing (DSB)

☐ off ☒ on

Specify source beam energy or spectrum filename

☐ monoenergetic ☒ spectrum

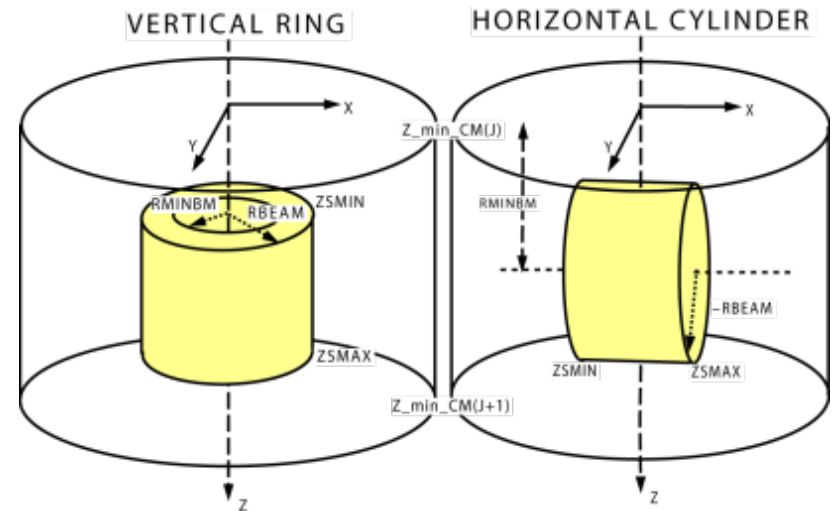
Kinetic energy of beam (MeV)

Spectrum filename (complete):

Output spectrum listing file?

include spectrum data in output summary

OK Help



- 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)

Directional Source Biasing Parameters

Splitting field radius (cm) 10.0

Source to surface distance (cm) 95.

Photon splitting number 20000

CM for photon splitting/radial redistribution 2 (PRIMCOLL)

Min. linear distance between split photons (cm) 1.5

☐ Use rejection plane ☐ Z (cm) of rejection plane

CM for e-/e+ splitting 3 (ADJCOLL)

e-/e+ splitting plane no. 10 (Z=35.9 cm)

Z of Russian Roulette plane (cm) 35.0

Redistribution of split e-/e+
☒ Do not redistribute
☐ Radially-symmetric redistribution

☐ Augmented range rejection

Help OK

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

