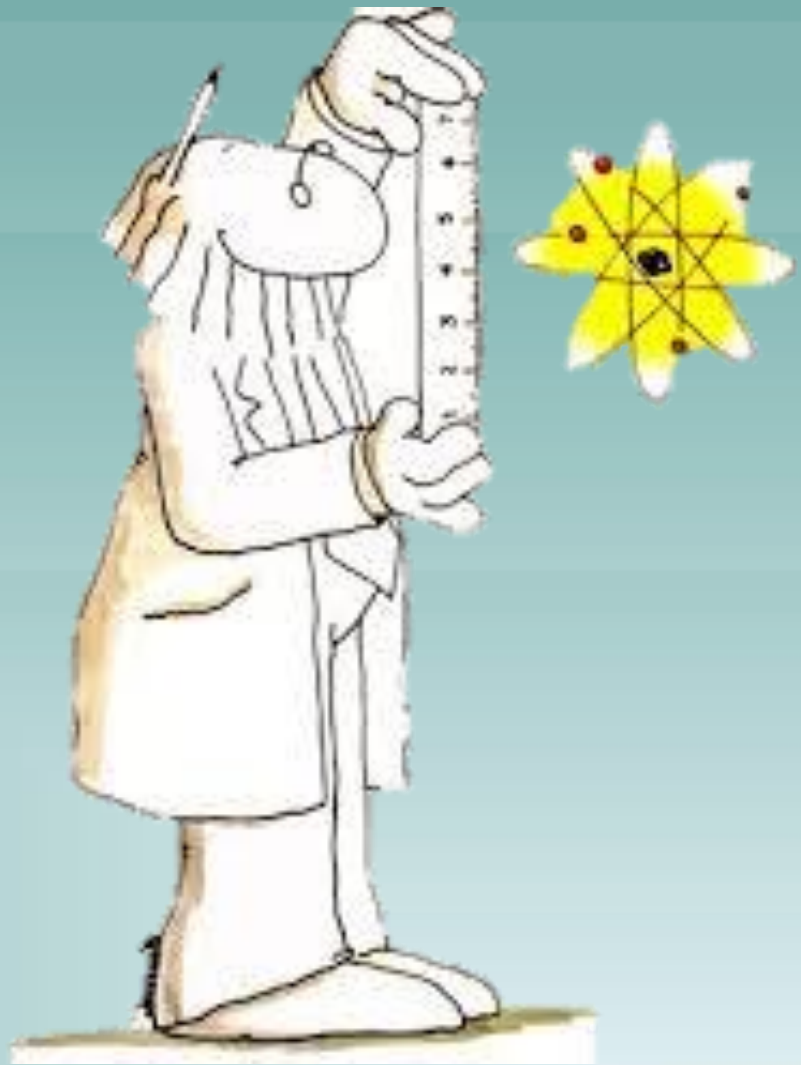
The EGSnrc Monte Carlo system

Corso Tecniche Monte Carlo – Aafke Kran –AA 2025/26

Speaker: Mariagrazia Celentano



Outline

- EGSnrc description
  - GitHub project: https://nrc-cnrc.github.io/EGSnrc/
  - Subreddit: https://www.reddit.com/r/EGSnrc/
  - Useful links for installation/user manuals:

    https://github.com/nrc-cnrc/EGSnrc/wiki/Installation-overview

    https://nrc-cnrc.github.io/EGSnrc/doc/pirs509a-beamnrc.pdf

    https://nrc-cnrc.github.io/EGSnrc/doc/pirs794-dosxyznrc.pdf

    https://nrc-cnrc.github.io/EGSnrc/doc/pirs898/

- Some examples

About the system

EGSnrc = Electron Gamma Shower toolkit developed by the National Research Council of Canada (NRC)

- Monte Carlo simulation of electron, photon and positrons through matter, from 1keV to 10GeV
- Elements Z = 1 · · · 100, arbitrary compounds and mixtures using the independent atom approximation
- Final release in 2000 by Kawrakow & Rogers
  - EGSnrc is now considered by many to be the "golden standard" in the Medical Physics community (200+ citations)

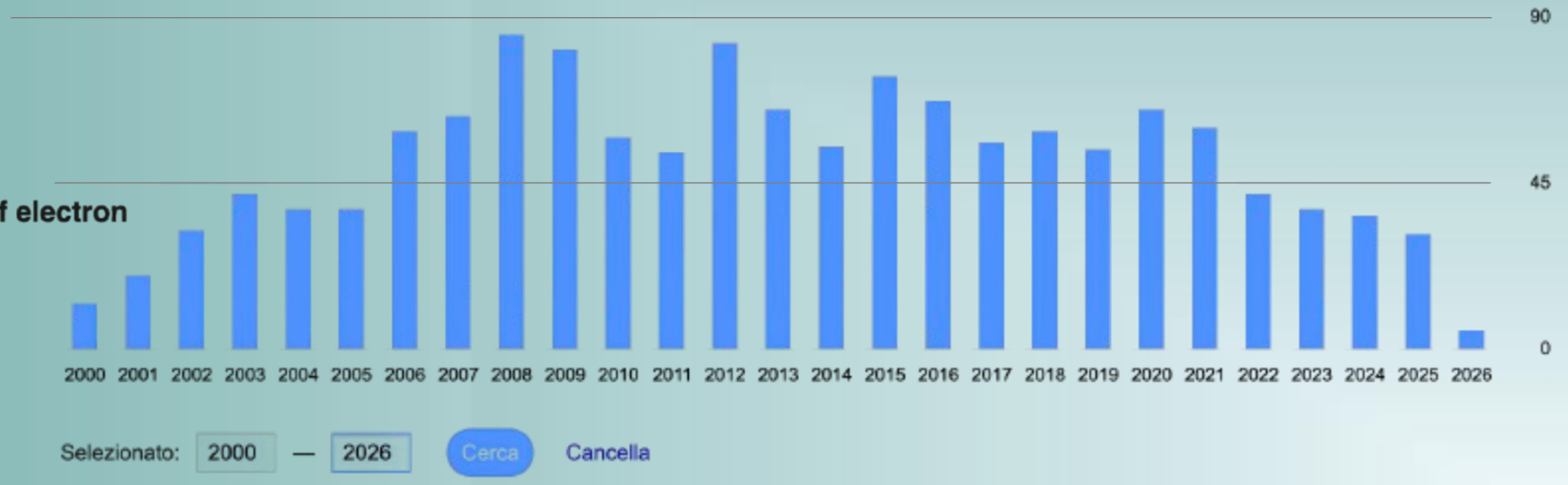
MEDICAL PHYSICS
The International Journal of Medical Physics Research and Practice

Radiation treatment physics

Accurate condensed history Monte Carlo simulation of electron transport. I. EGSnrc, the new EGS4 version

I. Kawrakow

First published: 08 March 2000 | https://doi.org/10.1118/1.598917



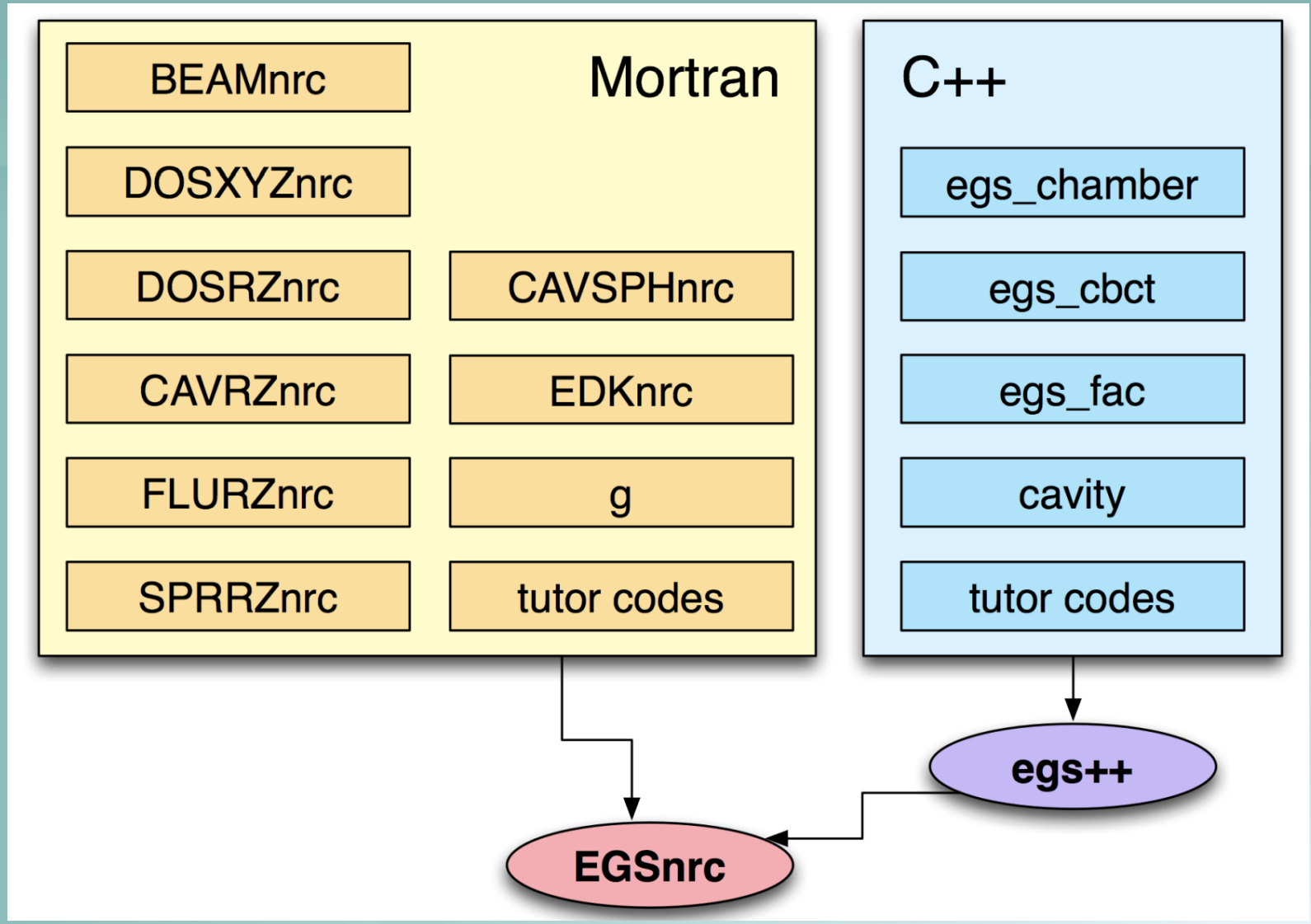
Different applications

There is no need write the code from the start

- The routines and codes distributed with EGSnrc are useful for a wide range of calculations

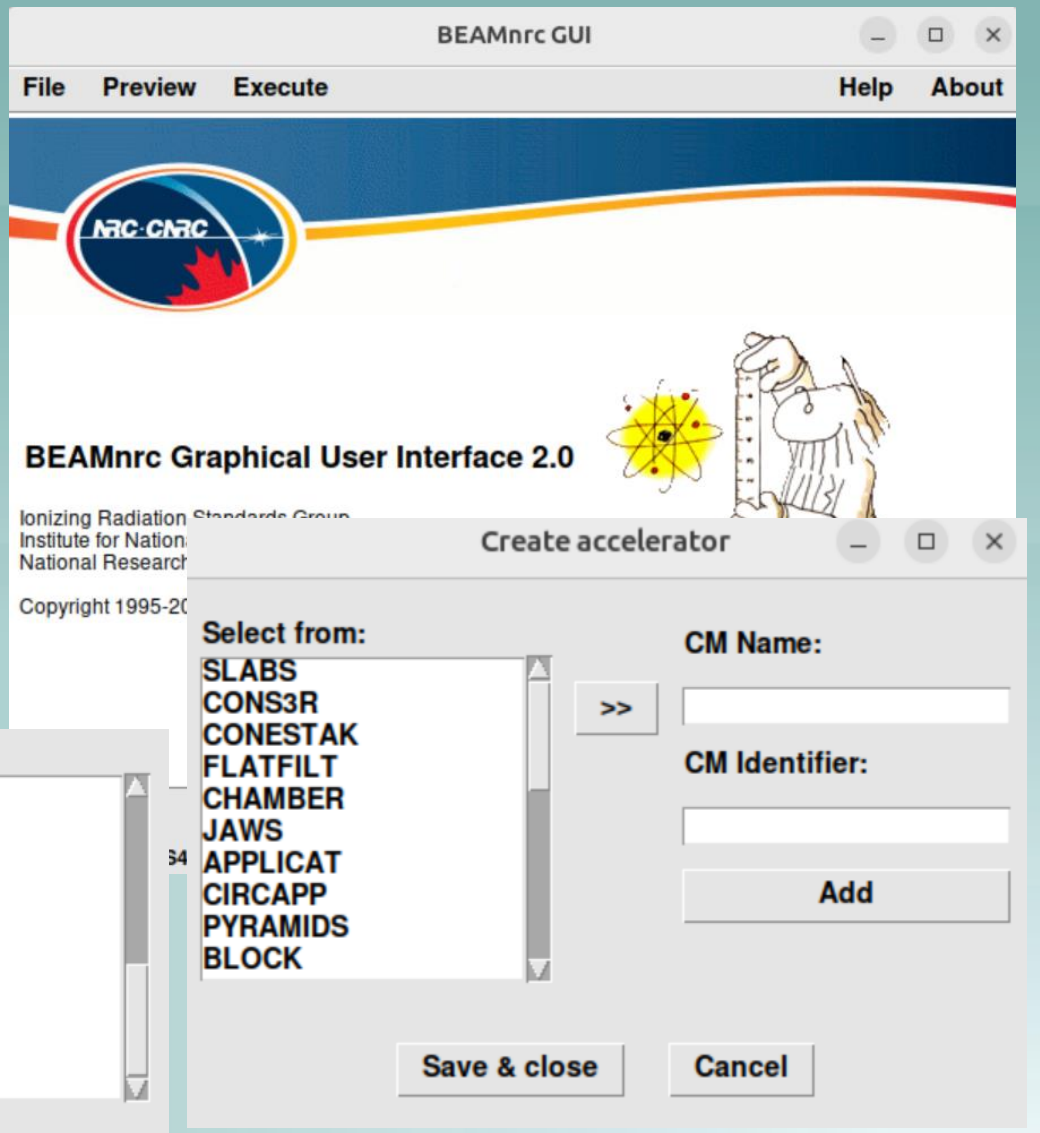
Each application is structured as:

- Input file reading
- Initialization of sorce and geometry
- Output definition (i.e. dose scoring)

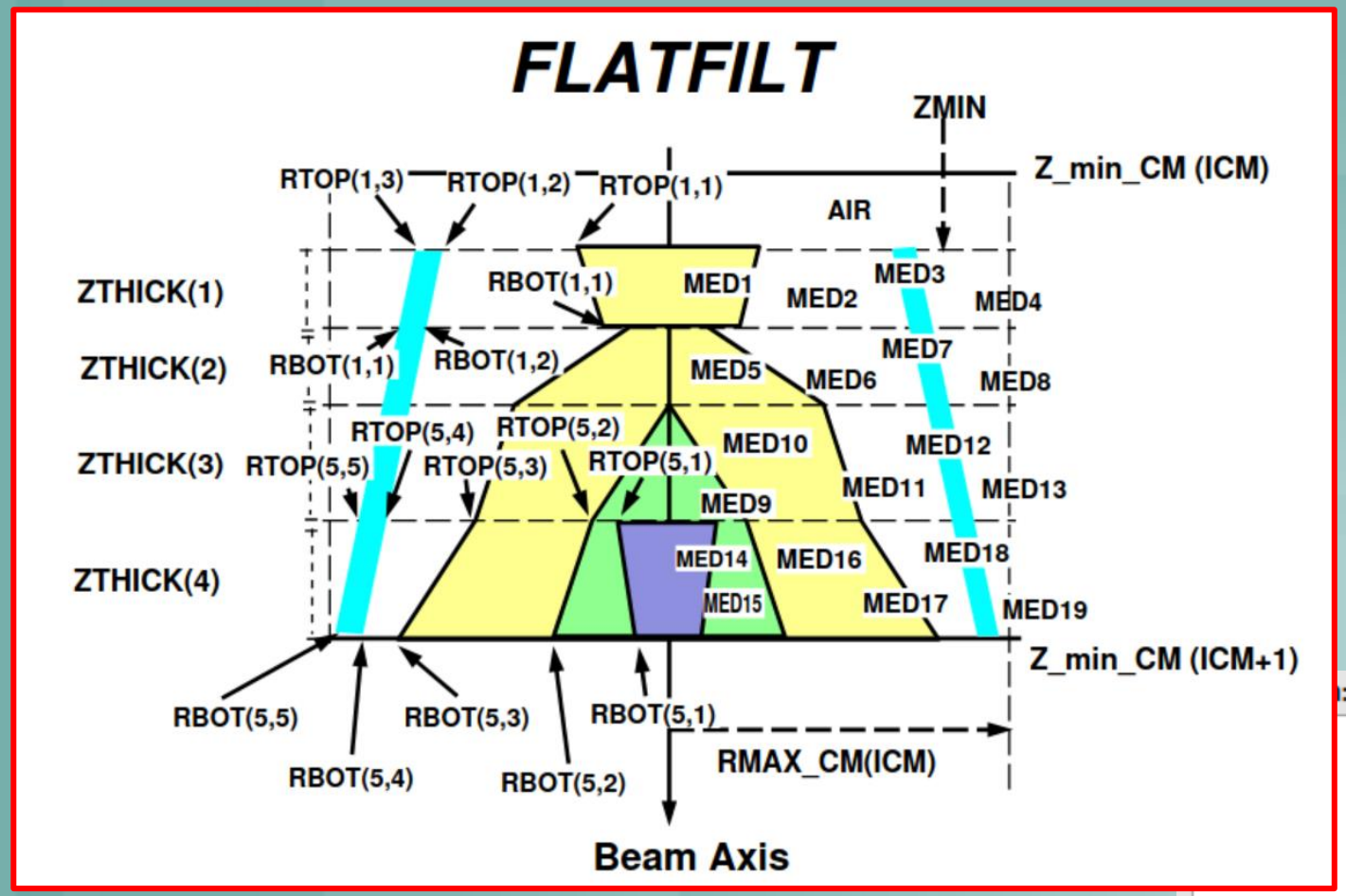


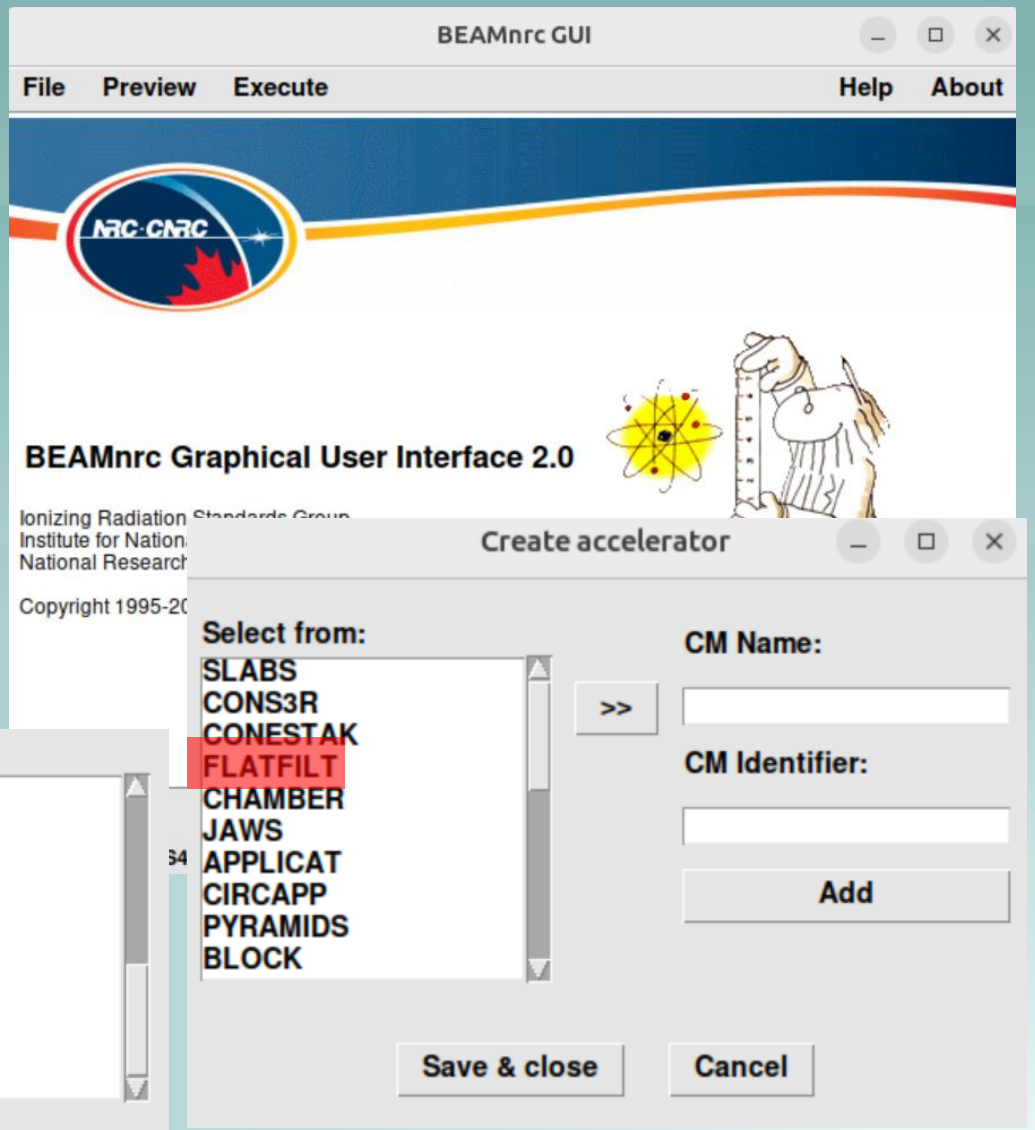
Different applications

1. BEAMnrc ⇒ linear accelerator modelling and x-ray systems
   - Includes geometries that can easily represent flattening filters, collimators, MLCs, etc.
   - Accelerators can be compiled as shared libraries to be used as a particle source for other applications
   - Includes time-synchronized capabilities (e.g. dynamic jaws and MLCs)



Different applications





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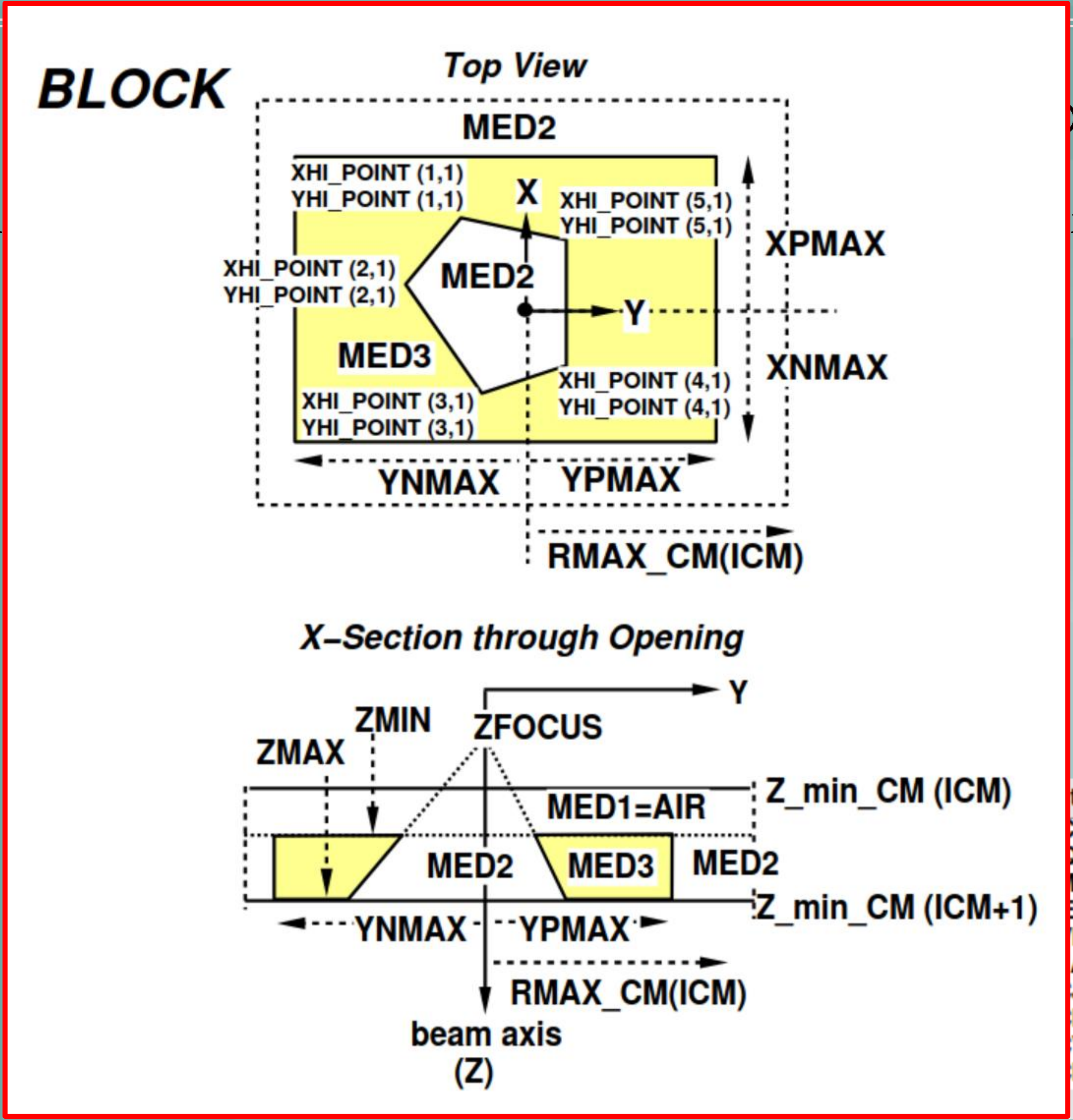
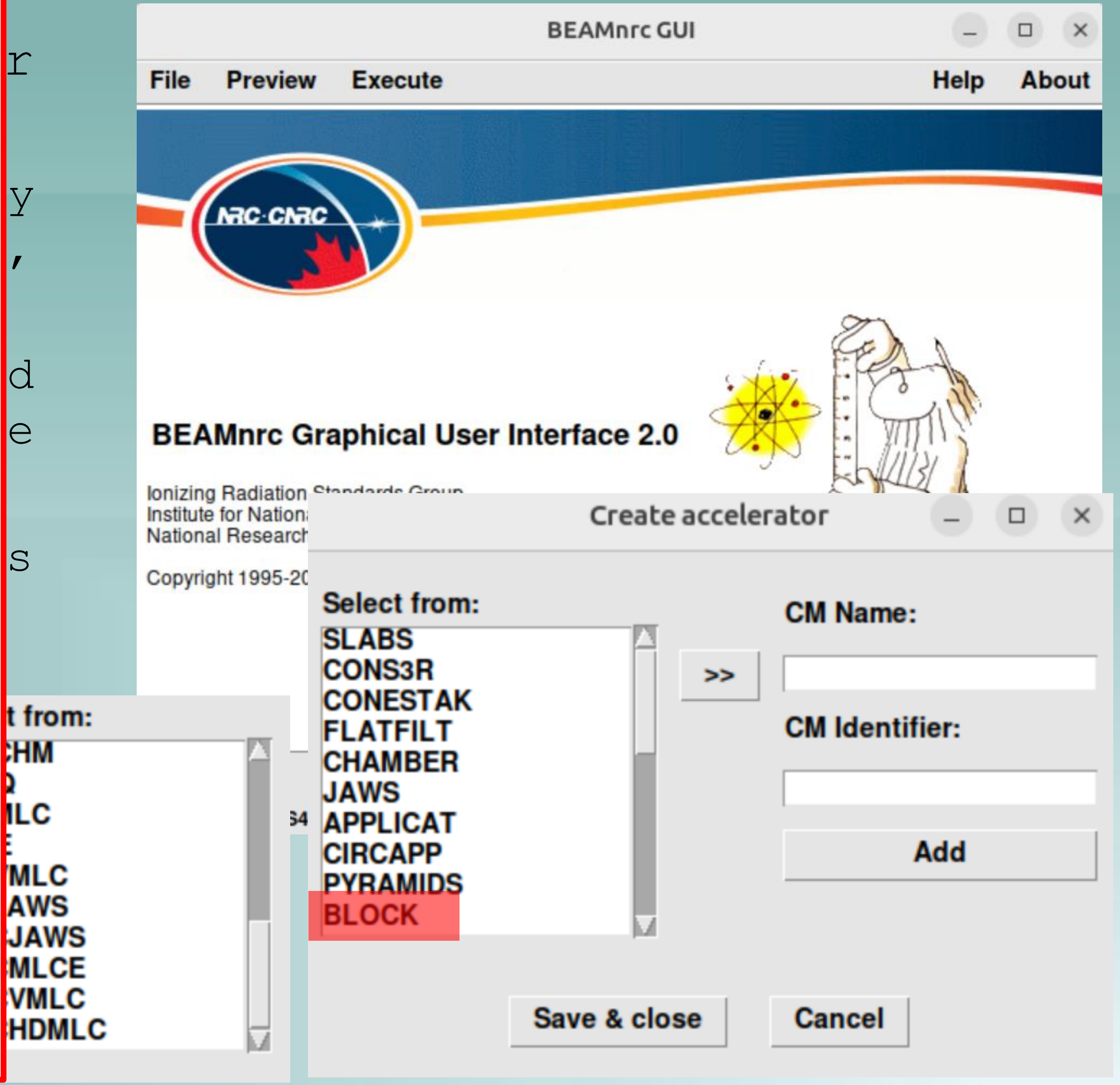


BLOCK
Top View
MED2
XHI_POINT (1,1)
YHI_POINT (1,1)
X
XHI_POINT (5,1)
YHI_POINT (5,1)
XPMAX
XHI_POINT (2,1)
YHI_POINT (2,1)
MED2
Y
MED3
XNMAX
XHI_POINT (4,1)
YHI_POINT (4,1)
XHI_POINT (3,1)
YHI_POINT (3,1)
YNMAX
YPMAX
RMAX_CM(ICM)
X–Section through Opening
Y
ZMIN
ZFOCUS
ZMAX
Z_min_CM (ICM)
MED1=AIR
MED2
MED3
MED2
Z_min_CM (ICM+1)
YNMAX
YPMAX
RMAX_CM(ICM)
beam axis
(Z)



BEAMnrc GUI
File
Preview
Execute
Help
About
BEAMnrc Graphical User Interface 2.0
Create accelerator
Select from:
SLABS
CONS3R
CONESTAK
FLATFILT
CHAMBER
JAWS
APPLICAT
CIRCAPP
PYRAMIDS
BLOCK
>>
CM Name:
CM Identifier:
Add
Save & close
Cancel

applications

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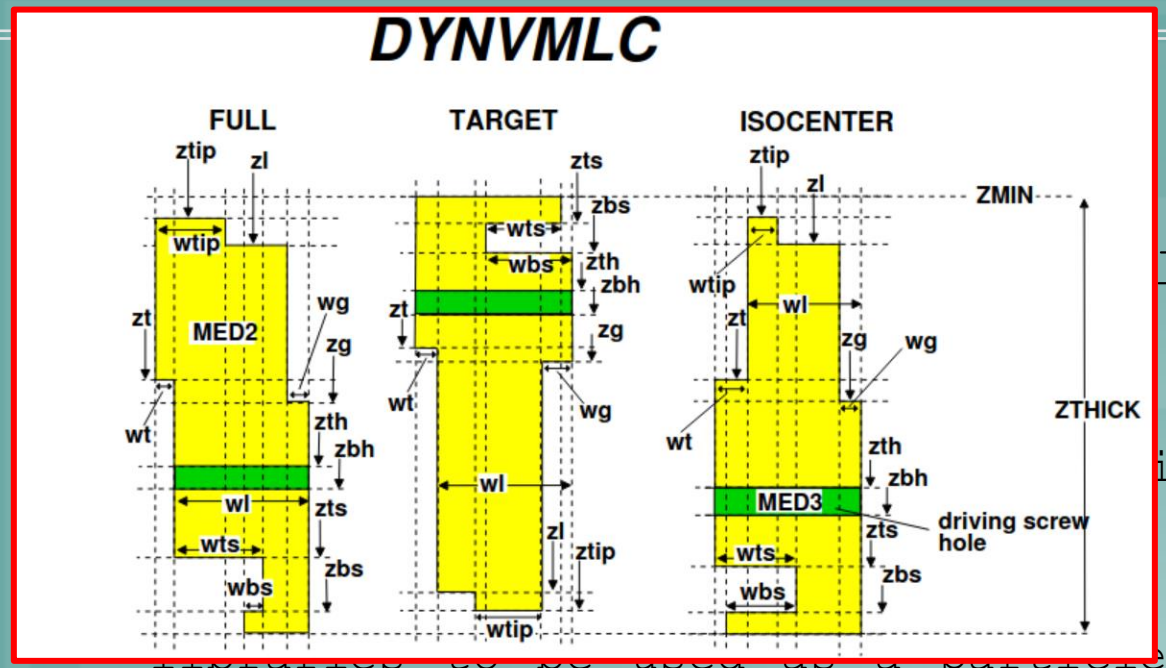

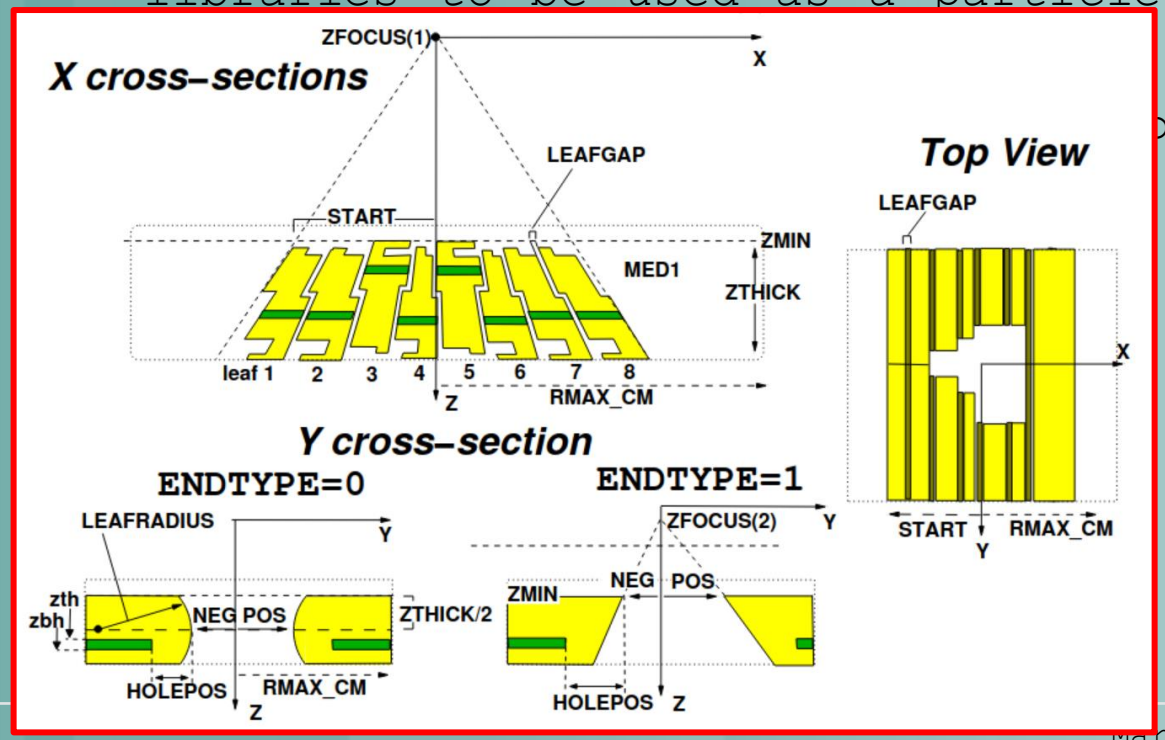

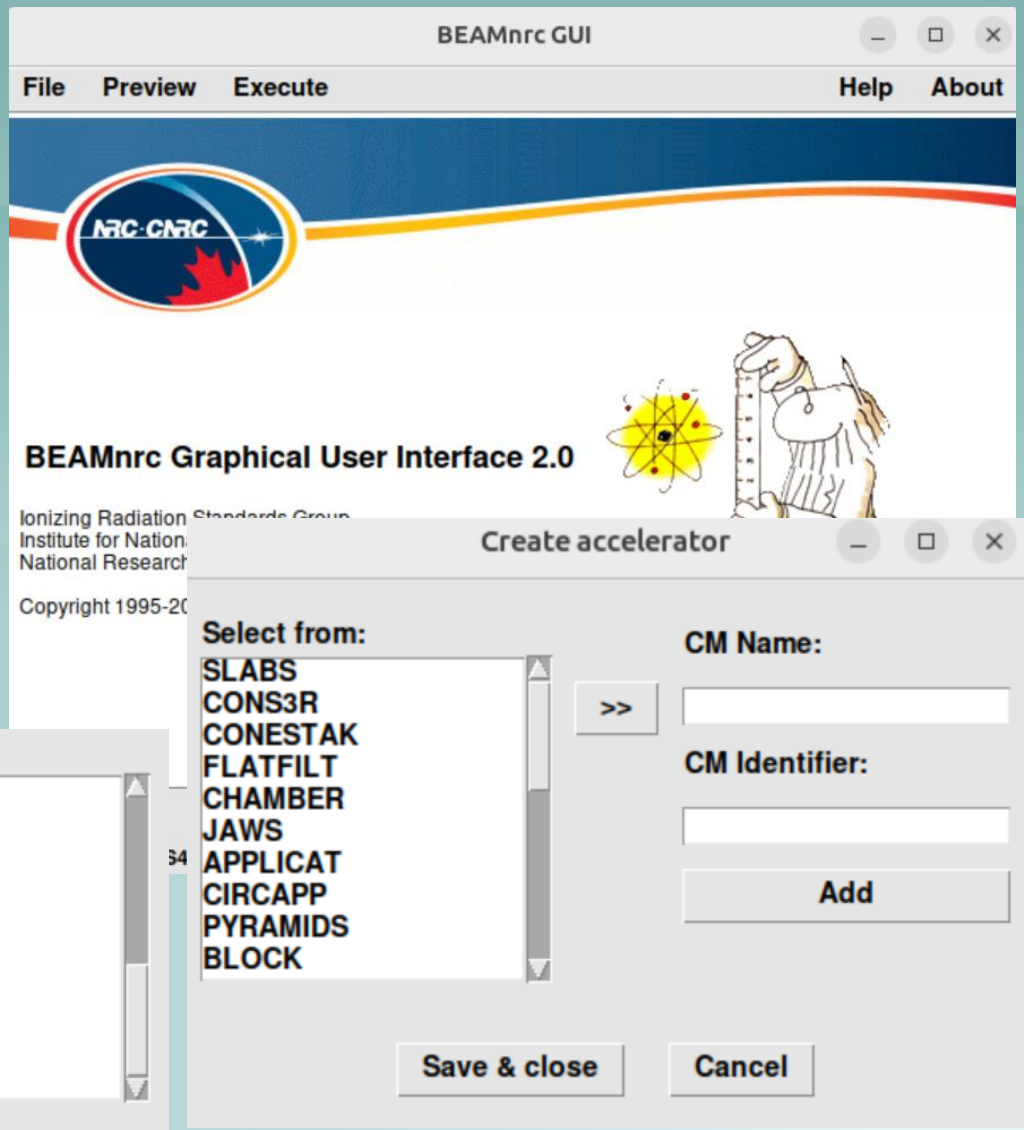

Different applications

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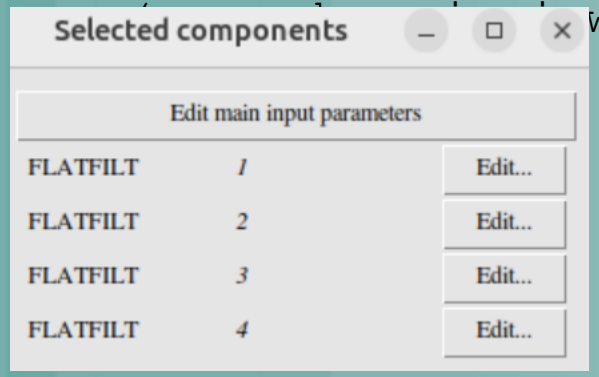
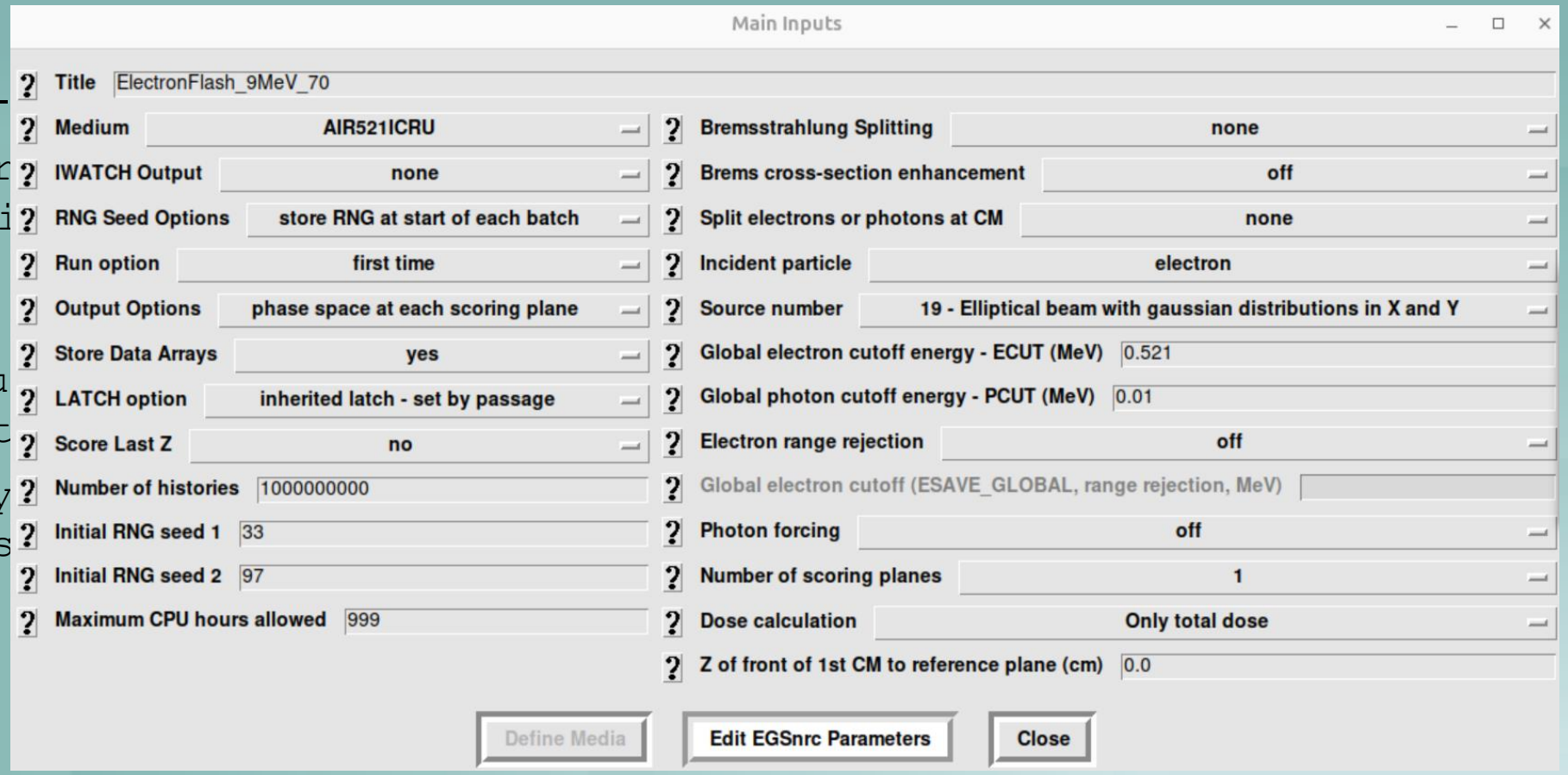
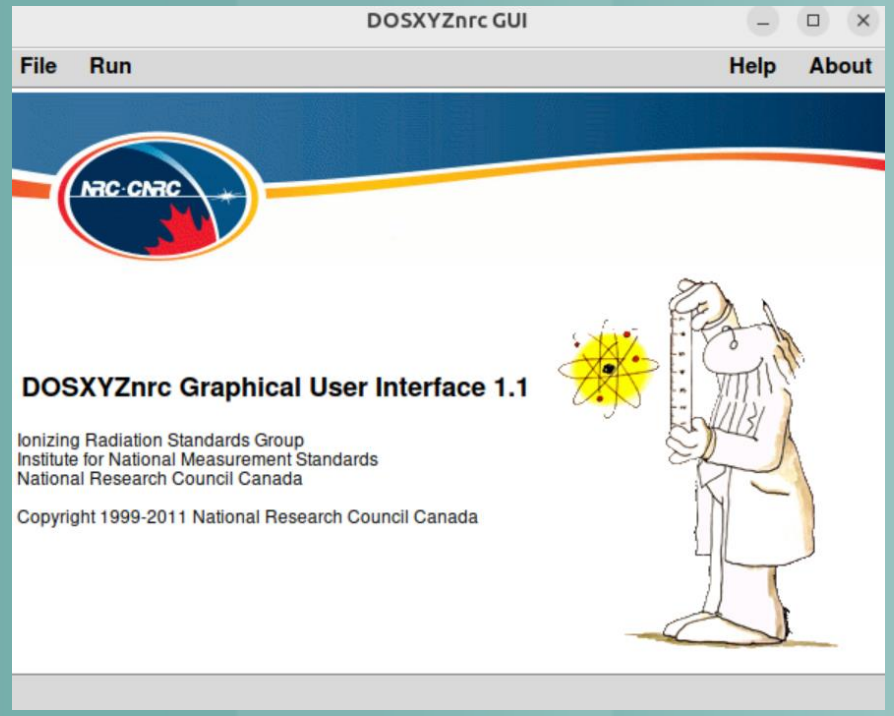
   - Includes geometr represent flatteni MLCs, etc.
   - Accelerators can libraries to be u for other applicat
   - Includes time-sy

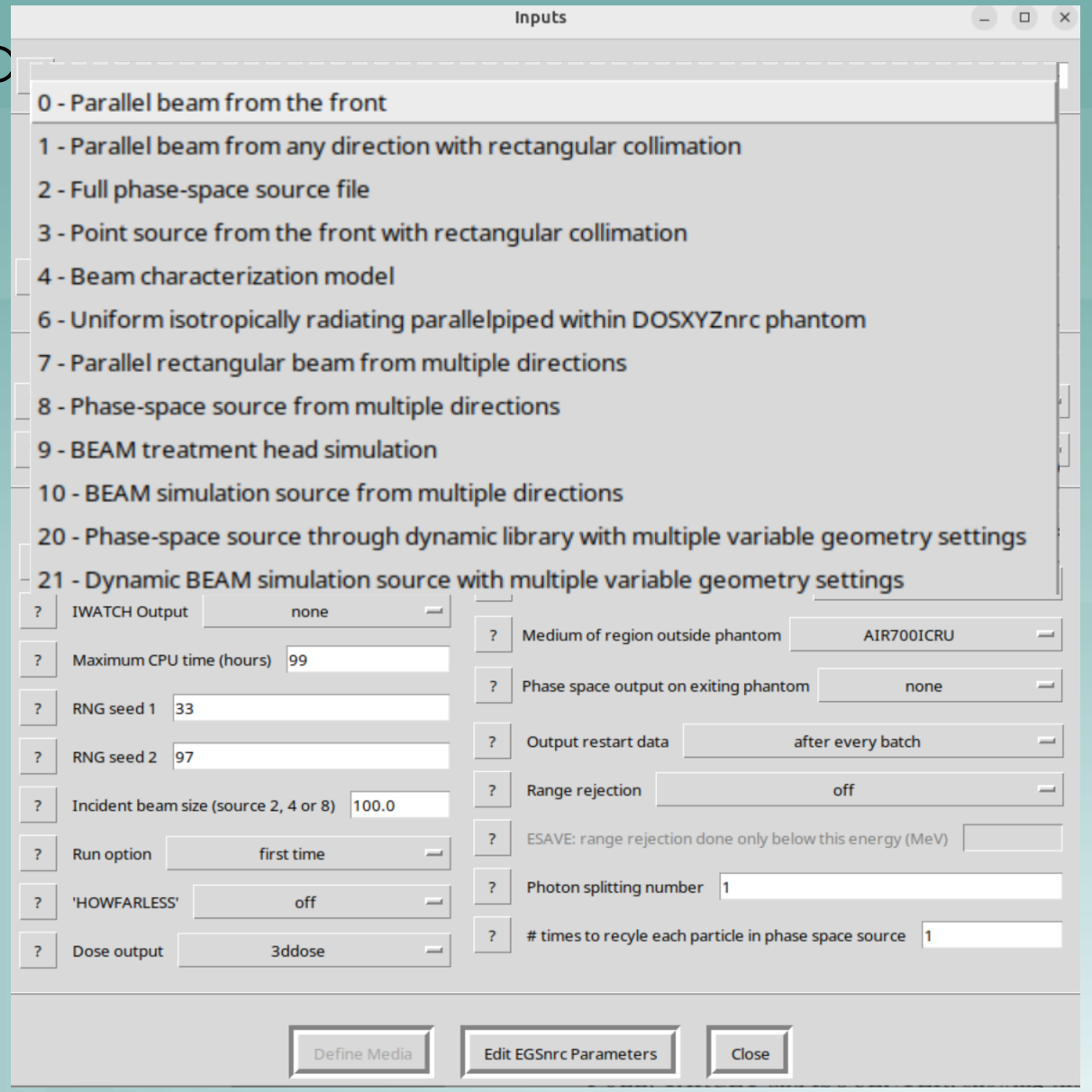




Different ap

2. DOSXYZnrc ⟹ dose calculations in voxelized phantoms
   - Includes a variety of source models (e.g. a BEAMnrc shared library)
   - Includes time-synchronized capabilities





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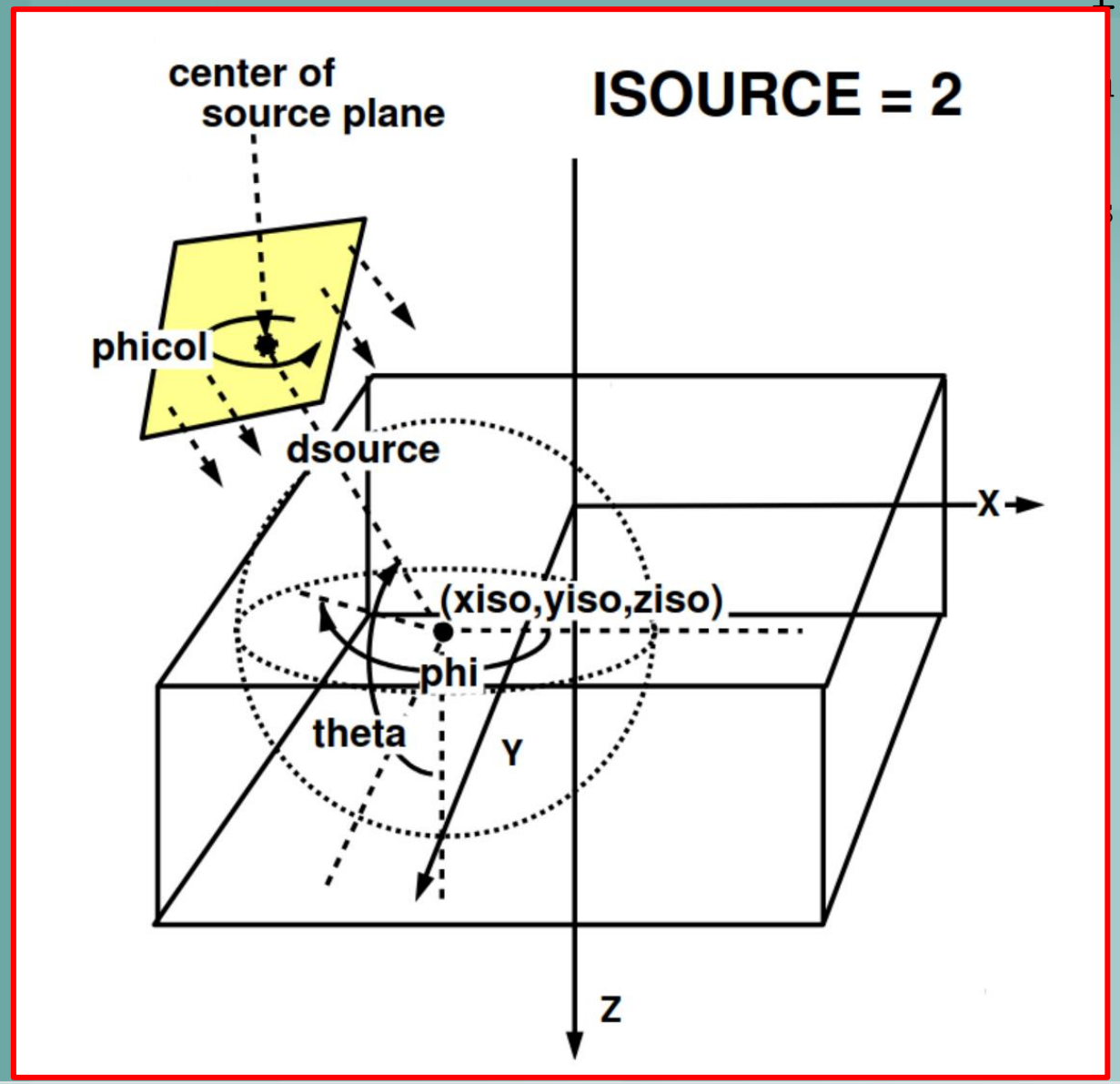
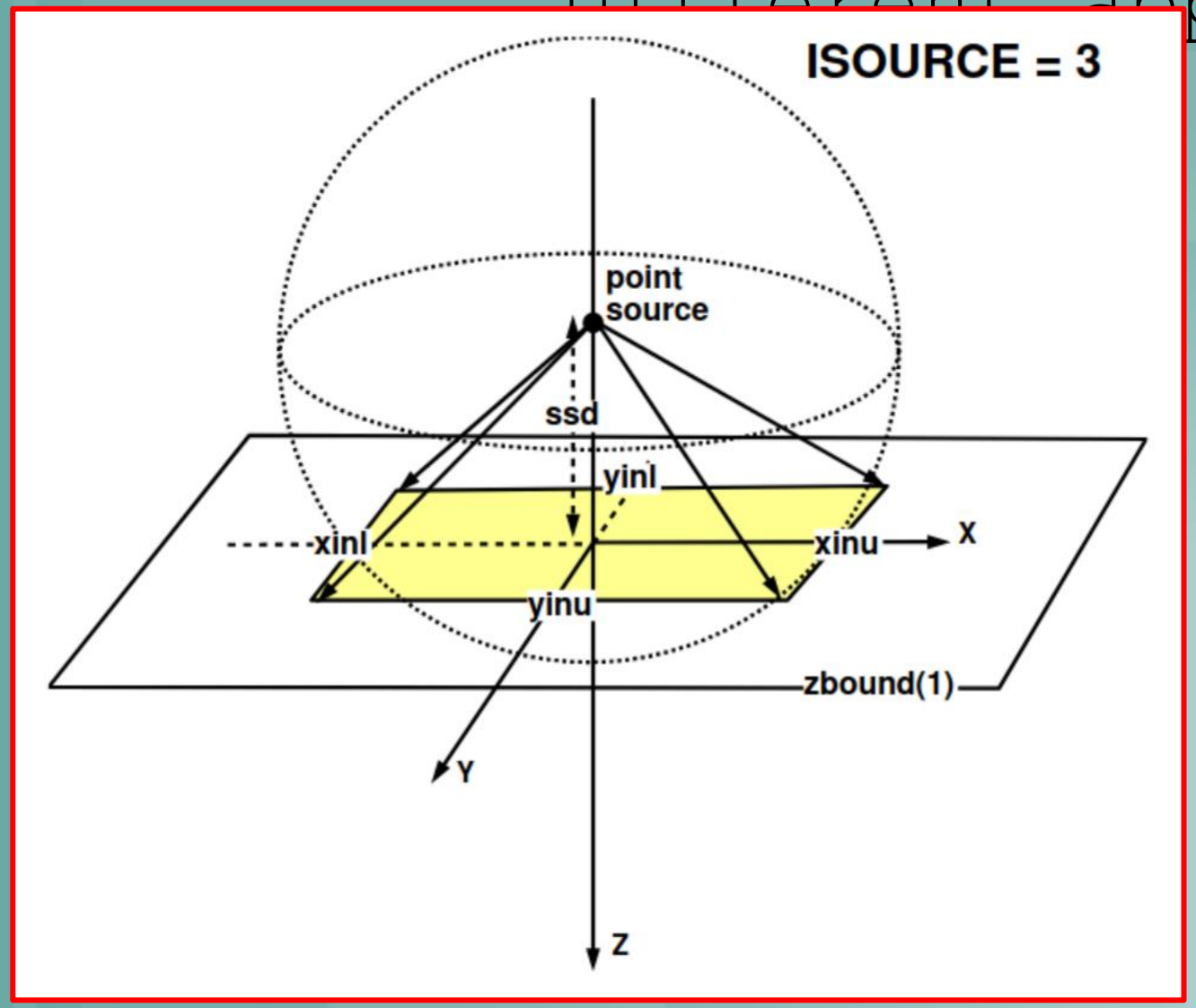


0 - Parallel beam from the front
1 - Parallel beam from any direction with rectangular collimation
2 - Full phase-space source file
3 - Point source from the front with rectangular collimation
4 - Beam characterization model
6 - Uniform isotropically radiating parallelpiped within DOSXYZnrc phantom
7 - Parallel rectangular beam from multiple directions
8 - Phase-space source from multiple directions
9 - BEAM treatment head simulation
10 - BEAM simulation source from multiple directions
20 - Phase-space source through dynamic library with multiple variable geometry settings
21 - Dynamic BEAM simulation source with multiple variable geometry settings

Different applications



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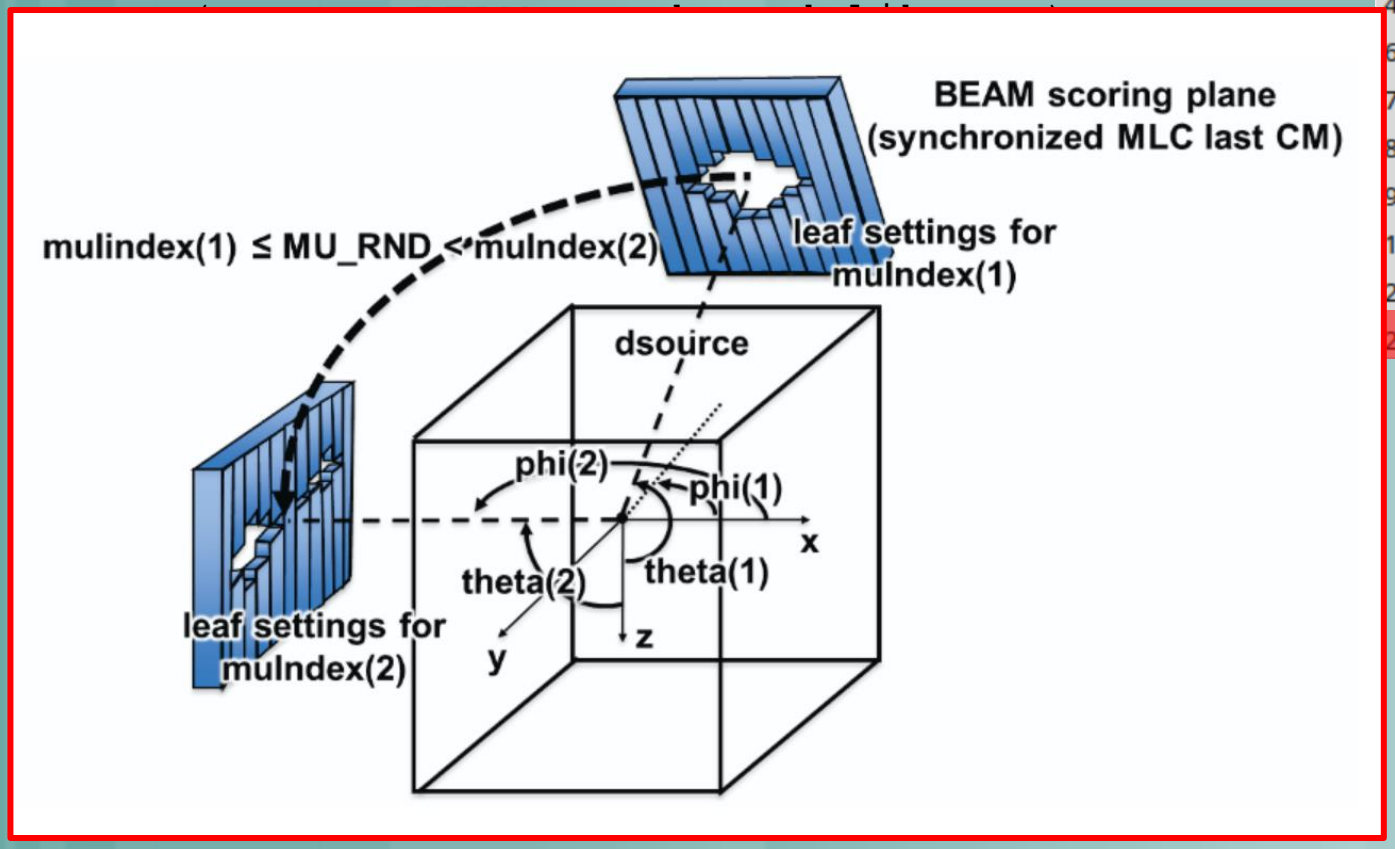

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Different applications

3. RZ applications ⟹ specific for cylindrical symmetry
   - DOSRZnrc = Dose and kerma calculations
   - CAVRZnrc = Calculates ionization chamber correction factors and relevant quantities Includes geometries that can easily represent flattening filters, collimators, MLCs, etc.
   - FLURZnrc = Particle fluence calculations
   - SPRRZnrc = Calculates Spencer-Attix spectrum averaged stopping-power ratios for arbitrary media

4. SPH applications ⟹ specific for spherical symmetry
   - CAVSPHnrc = Identical to CAVRZnrc but for spherical geometries
   - EDKnrc = Calculates energy deposition kernels for photons or electrons forced to interact at the centre of a spherical phantom. It also calculates dose distributions in the entire phantom or the dose to specific regions defined as the cavity of a spherical ion chamber Includes a variety of source models (e.g. a BEAMnrc shared library)

Different applications

5. g ⟹ calculates the energy fraction lost to radiation when electrons slow down (if the incident beam is photons), or the radiative yield (if the incident beam is electrons)
   - Calculates quantities such as μ_{tr} and μ_{en}

6. egs_chamber
   - Calculates dose and energy deposited in regions/media
   - Optimized for ionization chamber calculations
   - Many relevant variance reduction techniques

7. egs_fac
   - Designed for the purpose of calculating free air chamber (FAC) correction factors

Different applications

8. egs_cbct
   - Fast estimation of the scatter contribution to an ideal detector in a CBCT setup by means of sophisticated variance reduction techniques and a smoothing algorithm
   - Can also be used for estimating the total signal to the detector and its individual components: transmitted and scattered
   - Initially designed for the purpose of simulating a CBCT setup, but can be equally used for modelling conventional CT scanner setups

9. cavity
   - Calculates dose in ionization chamber and correction factors
   - The predecessor of egs_chamber and egs_fac

10. tutor app
    - Can use arbitrary geometry constructible with egspp
    - https://nrc-cnrc.github.io/EGSnrc/doc/pirs898/group__Geometry.html

Different applications

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bonus ⟹ egs_brachy
- not fully implemented in EGSnrc (yet!) but needs a separate installation
- Internal dosimetry with various $\gamma-$ and $\beta^{+/-}-$emitters
- https://clrp-code.github.io/egs_brachy/index.html

Analysis and visualization tools

1. dosxyz_show
   - Display of CT data and corresponding dose isolines (if specified)
   - If geometric phantom is saved in DOSXYZnrc file, it can be viewed

2. Beamdp
   - Simple analysis of phase-space file, spectra visualization, fluence and angular distributions

3. egs_view
   - Geometry 3D viewer and particle track plots
   - It can be used for .geom and .egsinp files (geometry) and .ptracks fikles (tracks)

4. EGS_Windows
   - Linux gui interface for interactive 3D visualization of BEAMnrc geometries and simulated particle tracks
   - Dedicated output files from BEAMnrc simulations with <1000 primary particles

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Analysis and visualization tools

5. BEAMnrc Preview
   - Generates a 2D diagram of the entire accelerator or the single part of accelerator
   - The third axis is always on 0cm and cannot be changed

6. VICTORIA (online) https://web.uvic.ca/~bazalova/VICTORIA/
   - Online dose viewer to display .egsphant, .3ddose files and DICOM CT, RTStruct and RTDose files
   - Normalization of dose distibution, plot of dose profiles and DVH
   - Not suited for large files

7. egs_gui
   - General gui to compile and execute every c++ and mortran application

EGSnrc installation process

Instructions:

- https://github.com/nrc-cnrc/EGSnrc/wiki/Installation-overview

Prerequisites:

- Install gfortran gcc g++ make tk grace libmotif-dev qt5-default qt5-qmake git

Download EGSnrc:

- git clone https://github.com/nrc-cnrc/EGSnrc.git

Configuration of EGSnrc:

- ./HEN_HOUSE/scripts/configure

It is possible to install EGSnrc on Windows, MacOs and Linux but I recommend using a Unix system!

VirtualBox machine with EGSnrc set and running!

- Ubuntu24.04.4.ova

Some examples

1. Generate accelerator geometry
2. Generate geometric phantom/ phantom from CT and calculate dose distribution
3. Generation of radiography starting from phantom
4. PDD for Farmer chamber / correction factors cylindrical chamber in water