Point-kernel-based 3D ray tracing gamma dose rate calculator

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Outline

- Problem description
- Methodology
- GUI and Input preparation
- Ongoing developement
- Pros and cons

Problem description

- At ITER there is a complex time dependent neutron and gamma radiation field which is modeled with MCNP based simulations as standard
- This method is robust and accurate but demands significant time for model preparation/runtime/post processing
- However some of the components of the radiation field may be modeled with other means:
  - Point kernel based 3D ray tracing for discrete decay gamma sources like: TCWS ^{16}N or ACP sources
  - To have a tool where easy to check design changes, assess uncertainties independently

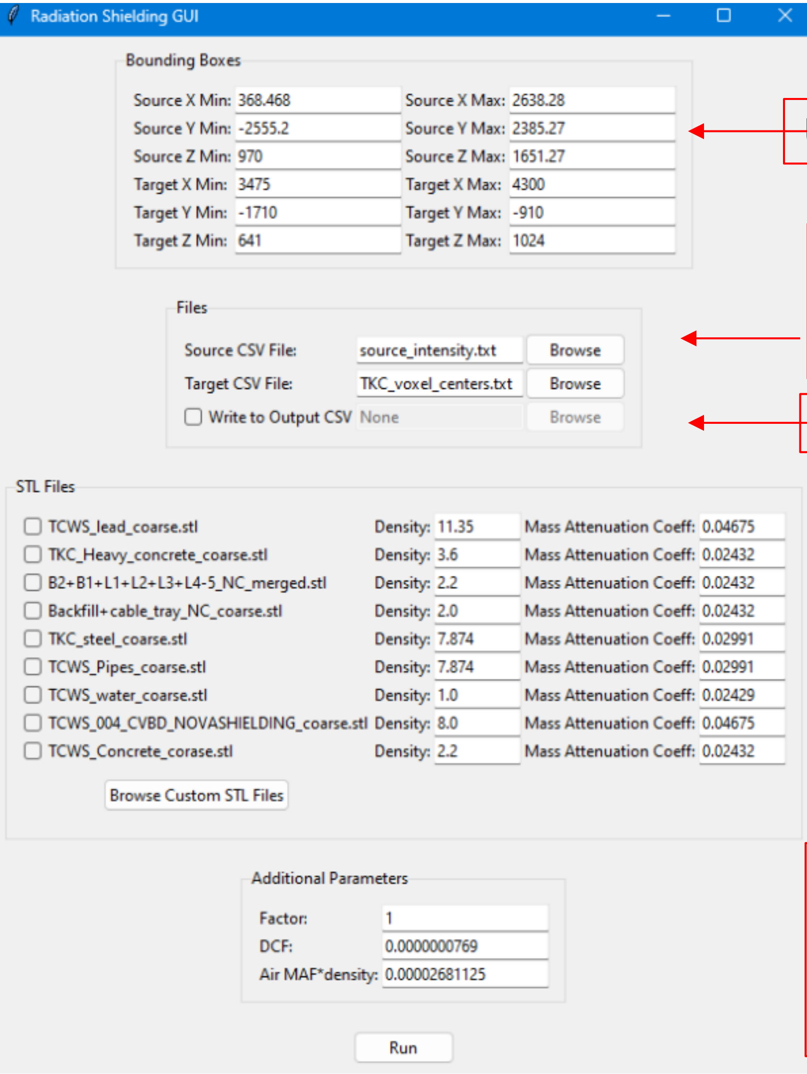
Methodology

- 3D point kernel method for dose rate calculation (monoenergetic):
  - $D(\bar{t}) = F * DCF * \sum_s I(\bar{s}) \frac{1}{4\pi r_s^2} \prod_i e^{-\rho_i \mu_i x_i}$
  - Where $\bar{t}$ denotes the target point, F is an arbitrary factor, DCF is the dose conversion factor, $\bar{s}$ denotes the source points, *I* is the intensity at each given source points, r_s denotes the distance between $\bar{s}$ and $\bar{t}$, ρ_i denotes the density of the ith material, μ_i denotes the mass attenuation coefficient of the ith material and x_i denotes the thickness of the ith material
- To determine the x_i the PyVista open source python ray tracing is used with stl geometry files

Methodology

- $D(\bar{t}) = F * DCF * \sum_s I(\bar{s}) \frac{1}{4\pi r_s^2} \prod_i e^{-\rho_i \mu_i x_i}$
- μ_i can be obtained from https://www.nist.gov/pml/x-ray-mass-attenuation-coefficients
- DCF values can be adjusted to values used in MCNP calculations
- $I(\bar{s})$ is an user input, for examplele the ^{16}N intensity along pipes
- ρ_i values can be adjusted to the values used in MCNP calculations
- r_s is trivial as the target and source points are all user inputs

GUI and Input preparation



User can restrict the source and target ROI

Source points and intensities as csv e.g.:
x,y,z,intensity
2619.00259,1680,1433,1.22E+16

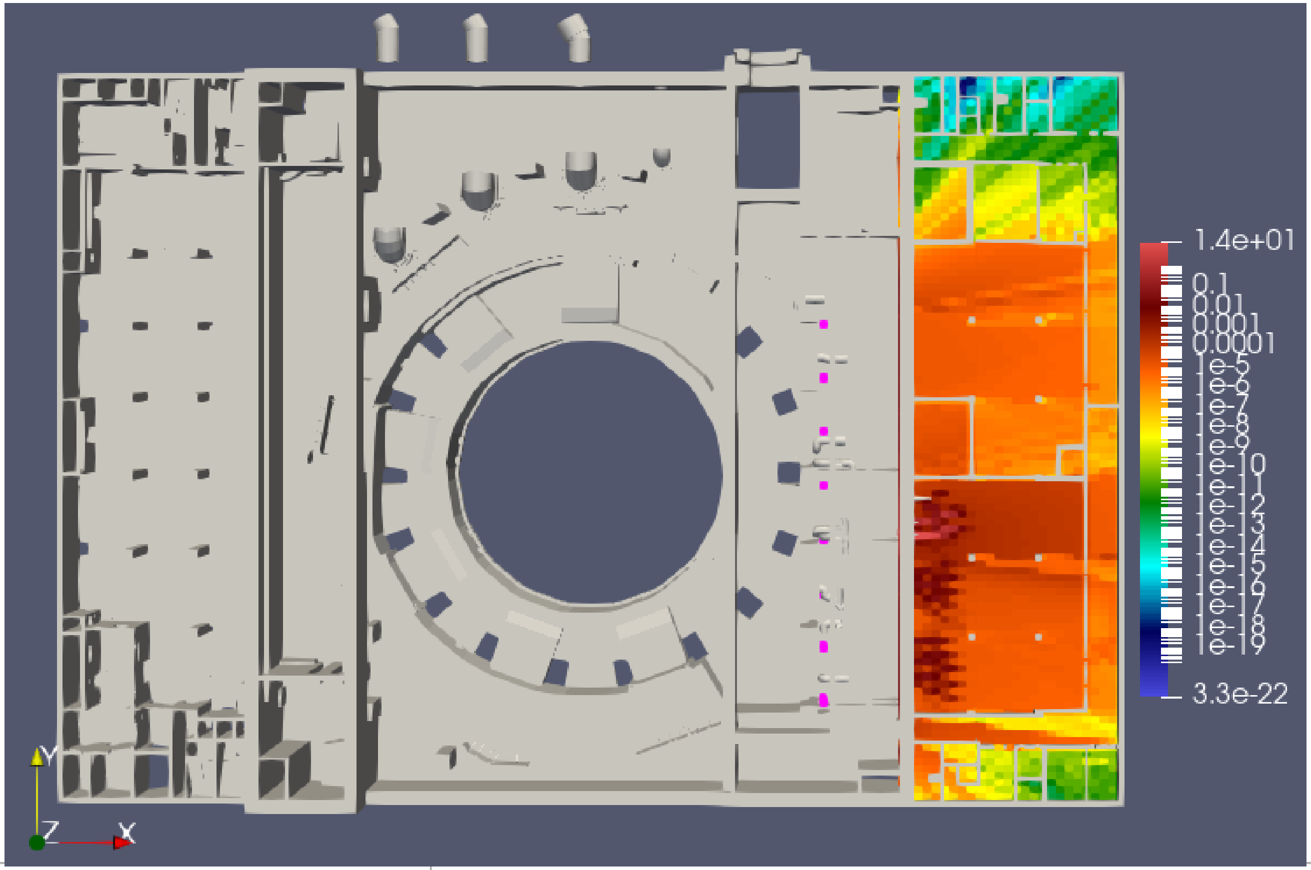
Target points as csv

Each material should be represented by a separate stl file
-Watertight, avoid overlapping regions
-it is possible to assign the density and mass attenuation coefficient for each material (geoemtry)

-F factor can be used, for build up or for safety factor
-DCF for the gamma energy of interest
-The VOID not defined in the geometry files is assumed to be air→ Air mass attenuation coefficient*Air density should be set

PRELIMINARY! Output example

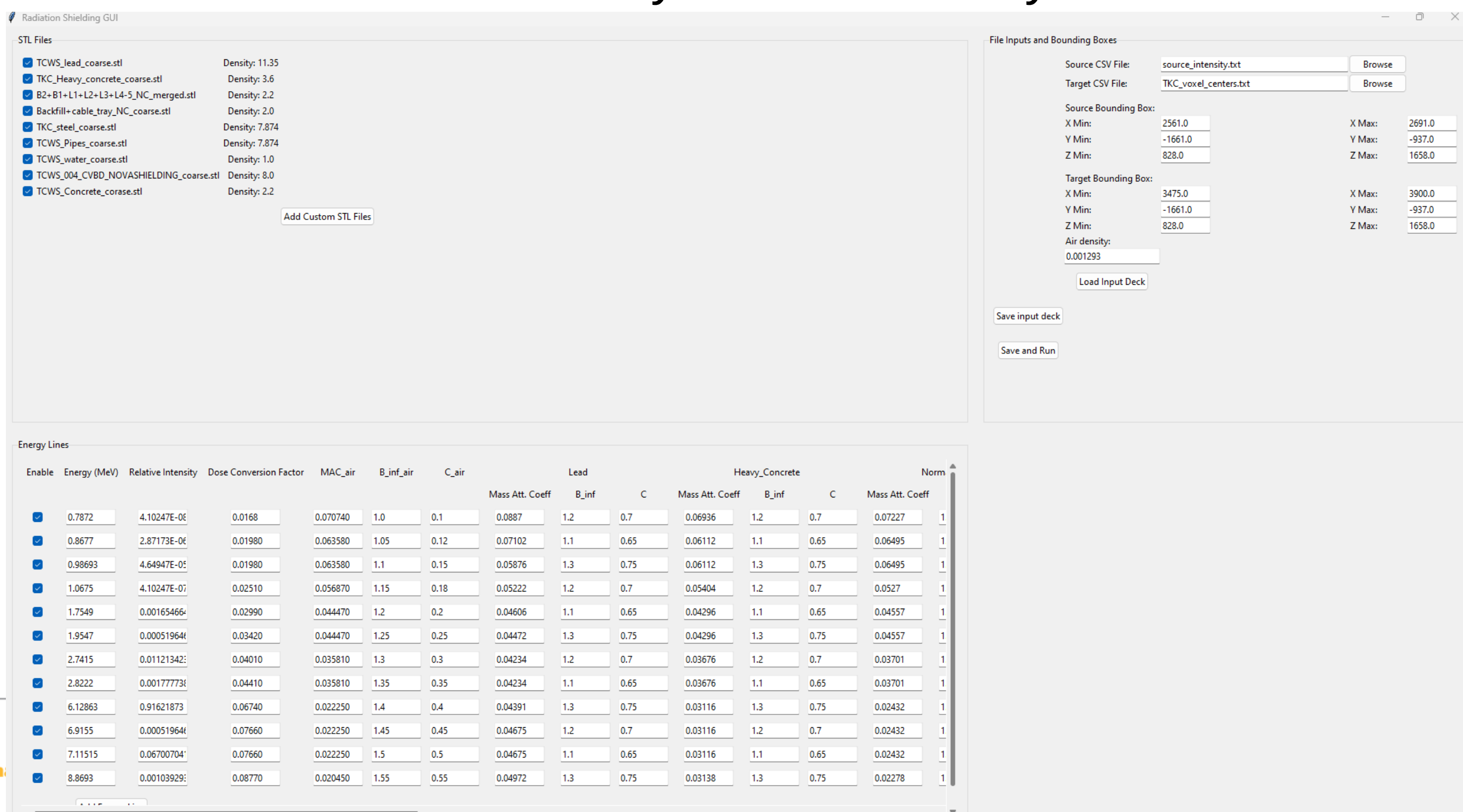
- Output is a vtk file



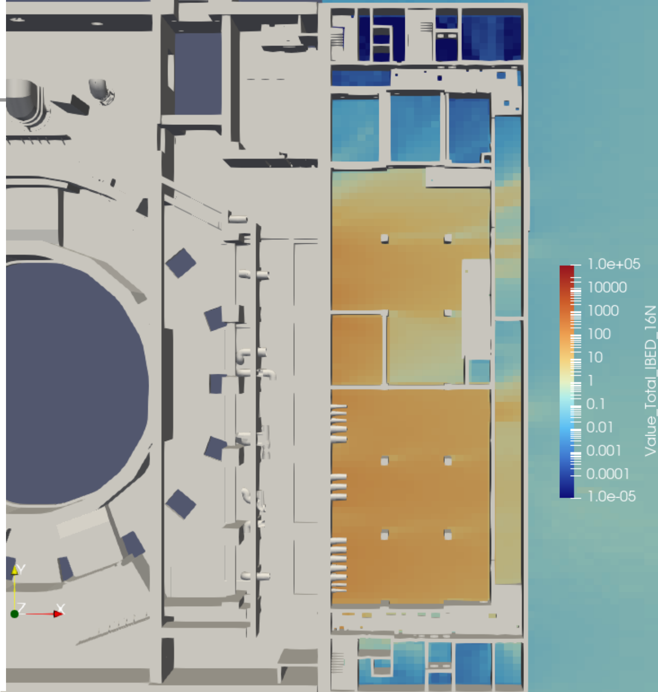
Performance for
24 source points at UPC
18928 target points:
~3.5 hours with 8 cores
Using geometries:
-TKC NC structures,
-TKC HC structures,
-TKC Steel structures
-Backfilling+cable tray

Ongoing developement

- Multiple energy line handling
- Energy and material dependent build up handling with e.g.:Geometrical Progression
- Cluster compatibility
- Input deck save and load
- To have a standard code for ^{16}N and ^{60}Co but still keep flexibility of the code
- Goal is to have the new version by the end of the year

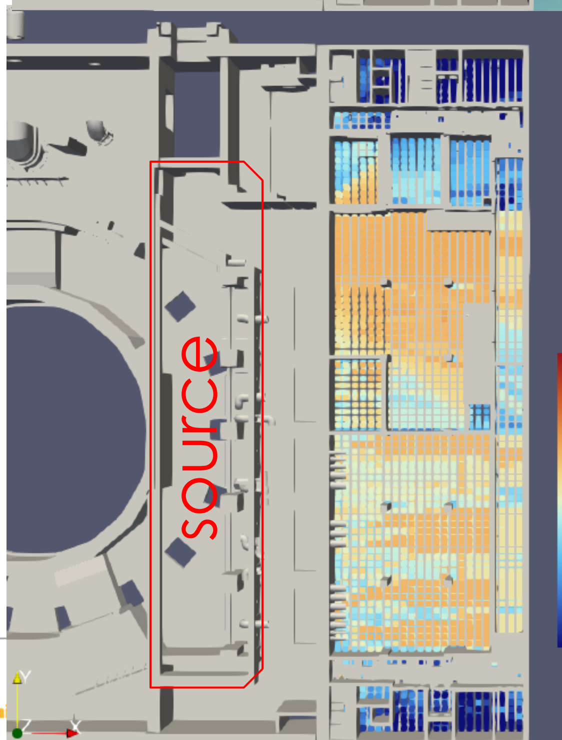


Radmap2020, IBED ^{16}N dose rate, Z=1308 cm



PRELIMINARY!

Point kernel based, no build up, Z=1308 cm



Performance
12 Energy lines of ^{16}N
1718 source points at UPC
15300 target points:
~43 hours with 8 cores
Using geometries:
-TKC NC structures,
-TKC HC structures,
-TKC Steel structures
-Backfilling+cable trays
-TCWS pipes
-TCWS water
-TCWS lead
-TCWS Novashield
-TCWS concrete

Pros and cons

- Pros:
  - Independent method from MCNP
  - 3D CAD geometry, no difficult geometry preparation
  - No special expertise is needed to use the code
  - Significantly less computational cost is foreseen
  - Quick results, for design or for comparative studies
  - May be used for error estimates
  - Point source approximation
- Cons:
  - Limited to gamma
  - Some phenomena can’t be modelled (skyshine, backscattering)
  - Point source approximation (more accurate for large distances)
  - Build-up approximation

Collaborators are welcomed!