Neutron shielding strategies for dose quantification in Neutron Capture Enhanced Particle Therapy

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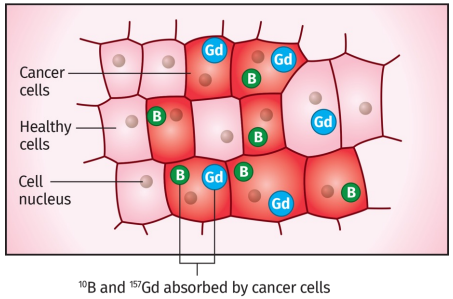
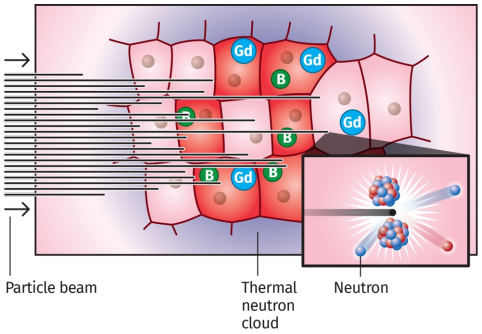
Neutron Capture Enhanced Particle Therapy

1



Tumor cells treated with targeted ^{10}B or ^{157}Gd bearing neutron capture agents

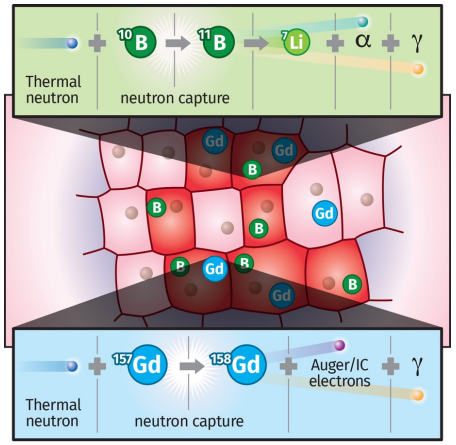
2



Particle beam (eg. p, ^{12}C or ^{16}O)

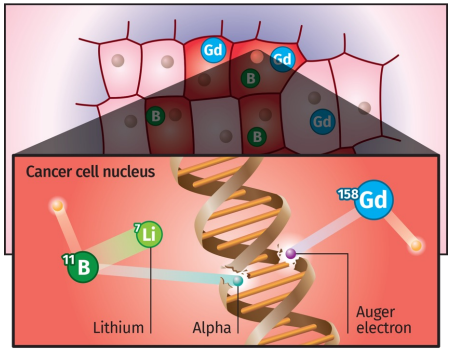
Collision with atoms in target area producing fragmentation products including thermal neutrons

3



Thermal neutrons captured by ^{10}B and ^{157}Gd

4



Auger electrons, lithium and alpha particles resulting from neutron capture create DNA double-strand breaks, predominantly killing cancer cells.

Quality assurance is difficult in NCEPT → Prompt gamma detection!

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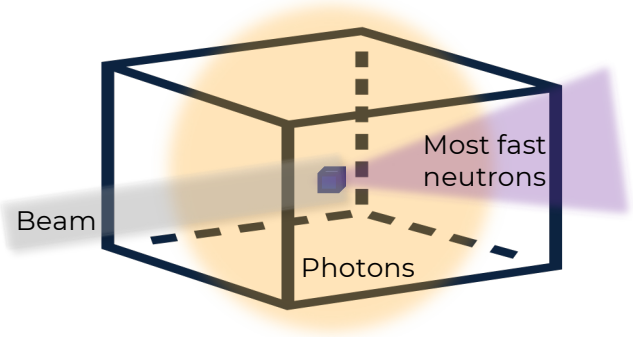
The photon and neutron mixed field

- Neutrons can interact to produce background counts in the photon spectrum
- May also cause activation of the detector/shield

Proposed solution:

- Position detector in forward-facing position
- Use temporal windows
- **Include neutron/photon shielding**



Shielding configurations

Full set

Front

- 0.41 cm polyethylene
- 0.04 cm gadolinium
- 0.04 cm Gd_2O_3

Side

- 1.30 cm polyethylene
- 1.24 cm polycarbonate
- 1.26 cm hafnium
- 1.10 cm Gd_2O_3
- 1.10 cm gadolinium
- 1.17 cm lead (1 TVL)

Simplified set

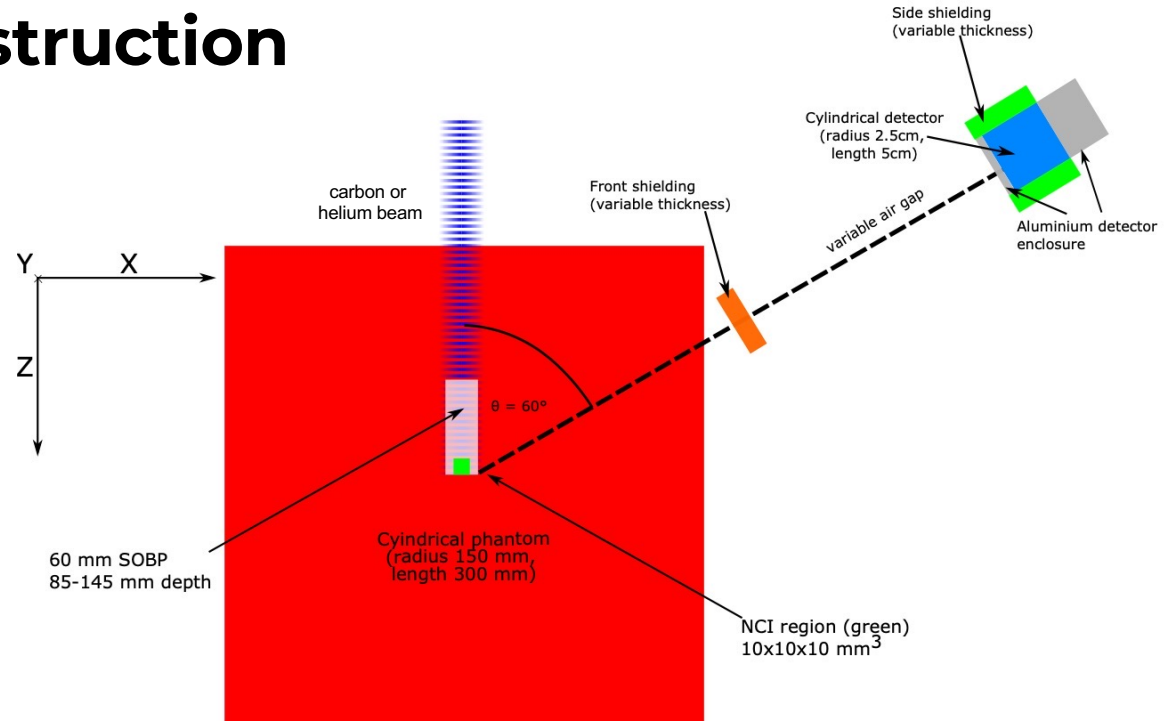
Front

- 0.8 cm polyethylene
- 0.02 cm Gd_2O_3

Side

- 5 cm polyethylene
- 1 cm gadolinium
- 1.17 cm lead (1 TVL)

Detector Construction



Variations in:

- Detector material – CdTe, CZT, $LaBr_3$:Ce
- Shielding – full set, simplified, no shielding

Investigating:

- Ratio of true to false positive counts
- Also looking at activation

Geant4 version 11 and BIC inelastic model, neutron high precision model

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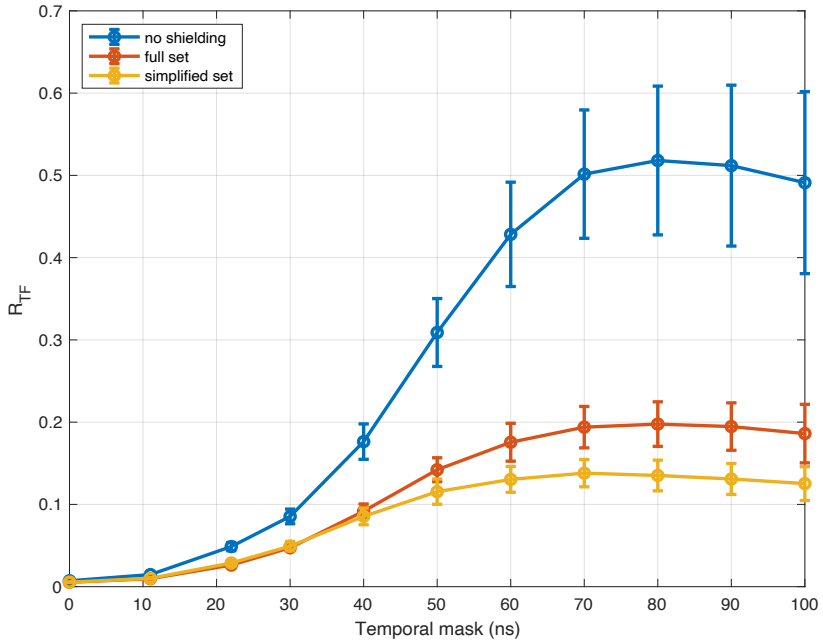
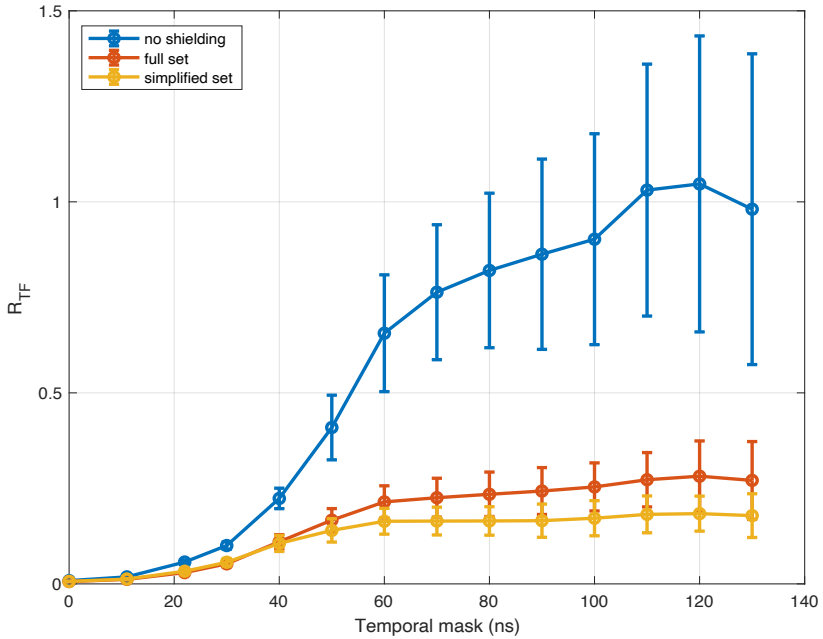
Measuring detector selectivity for CdTe – R_{TF}



^{12}C beam



^{4}He beam

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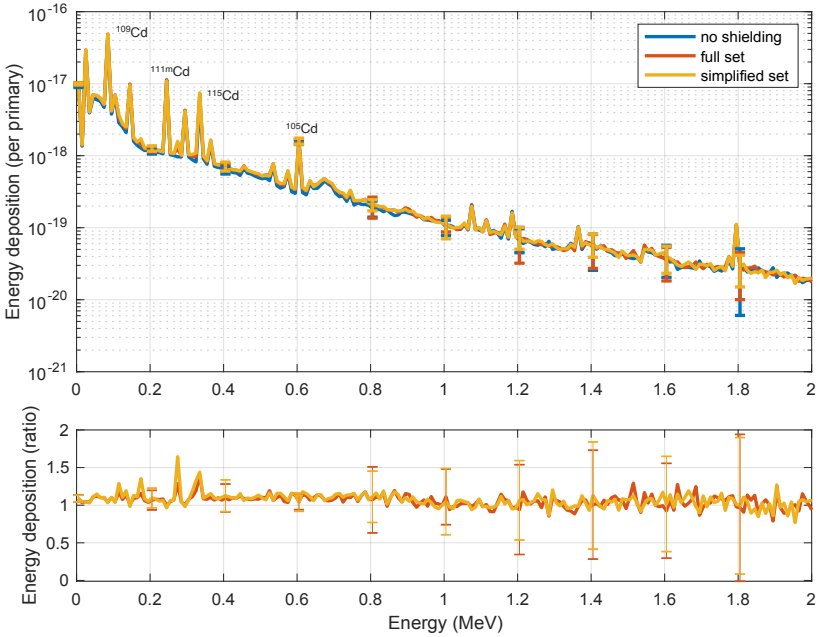
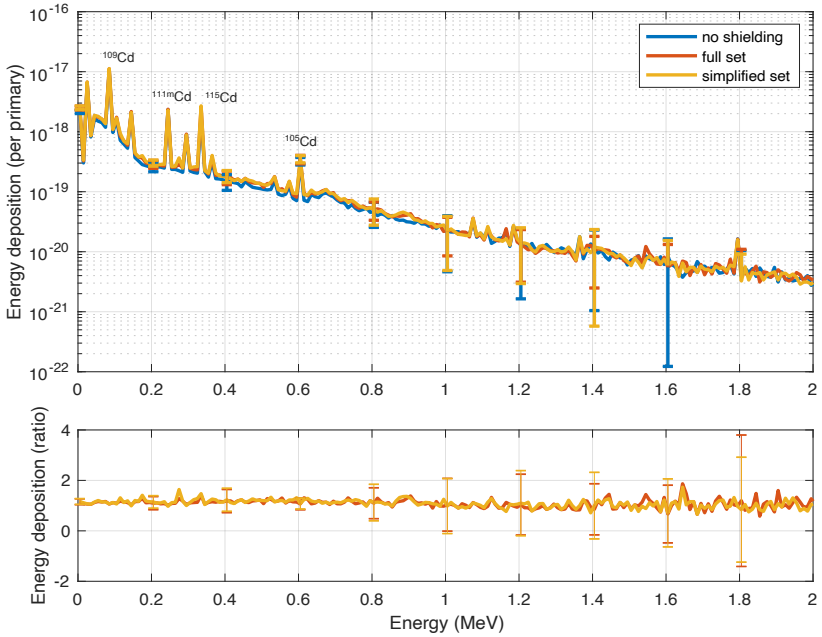
Detector activation – CdTe detector



^{12}C beam



^{4}He beam

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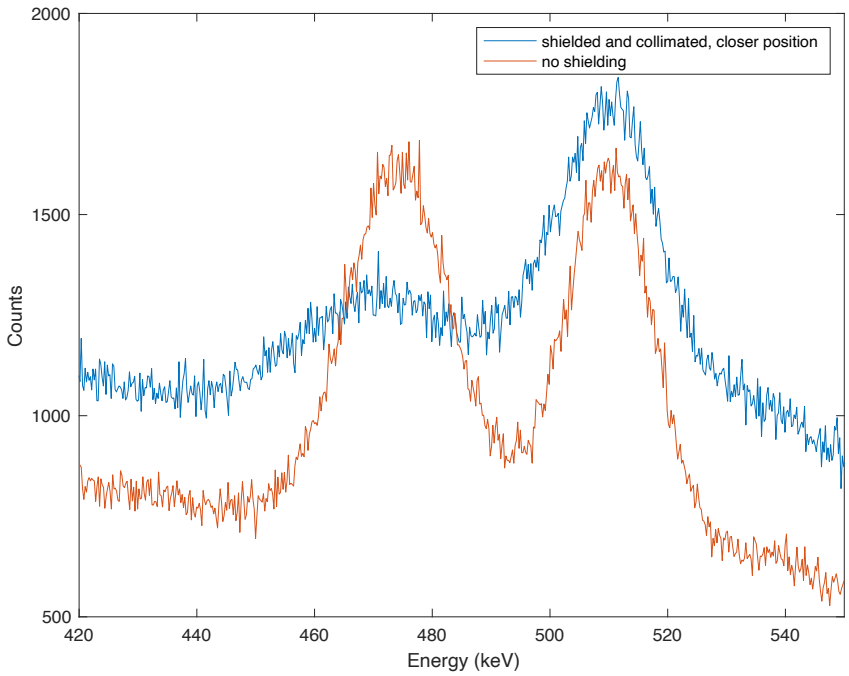
However, experimentally…

- Background spectrum contains a large peak at 478 keV
- Small increases in intensity cannot be seen – we need shielding!

How can we account for this?

- Model the room, so scattering is included
- Detector electronics can also be included in the model (contains boron)



Recent experimental result

Conclusions

Shielding

- Increases false positives
- Decreases R_{TF}
- Increases detector activation

Outcome

- Simulation model needs to be developed further, including PCBs
- Consider collimation strategies
- Vary phantom to detector distance

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Thank you!

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This work was undertaken with the support of the Australian Government Research Training Program Scholarship and the Australian Institute of Nuclear Science and Engineering (AINSE) Residential Student Scholarship

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Interaction	Energy Range	Geant4 Model
Radioactive Decay	N/A	G4RadioactiveDecayPhysics
Particle Decay	N/A	G4Decay
Hadron Elastic	0–100 TeV	G4HadronElasticPhysicsHP
Ion Inelastic	0–110 MeV 100 MeV–10 GeV 9.99 GeV–1 TeV	Binary Light Ion Cascade BIC FTFP
Neutron Capture	0–20 MeV 19.9 MeV–100 TeV	NeutronHPCapture nRadCapture
Neutron Inelastic	0–20 MeV 19.9 MeV–9.9 GeV	NeutronHPInelastic Binary Cascade
Neutron Elastic	0 eV–20 MeV 20 MeV–100 TeV	NeutronHPElastic hElasticCHIPS
Proton Inelastic	0–9.9 GeV	Binary Cascade