Low Energy Fusion For a Safe and Compact Neutron Source

Simon Albright
International Institute for Accelerator Applications
University of Huddersfield

Supervisor: Prof. R. Seviour

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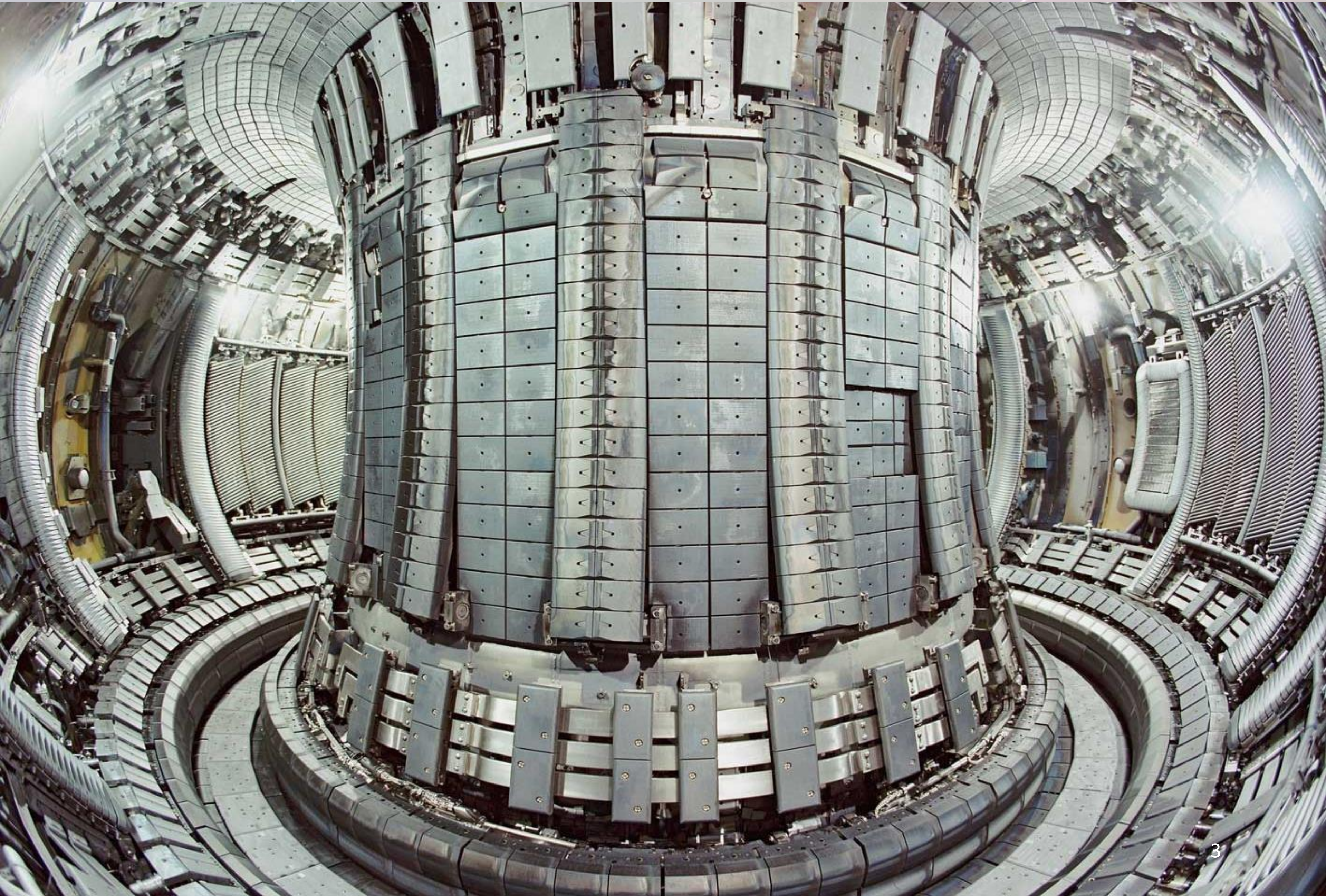
Fusion




CAUTION
RADIATION

Fusion Neutron Source

Tokamak:
- Heat Deuterium/Tritium gas mixture
- Thermal motion initiates fusion

Neutron Source:
- Stationary target nucleus
- Accelerator provides kinetic energy

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Neutron Sources

Fission:
- Uncontrollable
- Long-lived by products
- White spectrum

Sealed Tube Fusion Sources:
- Short life time
- Use/produce tritium

Spallation:
- Very large facilities
- High Technology
- Expensive

New Source:
- Compact
- High energy
- Short pulses
- High flux
- Clean

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X-Ray Scanning

- Line integral of density between source and detector
- Reliant on potential threats being seen by operator
- Can be enhanced by image recognition
- Large high density objects block X-Rays

Security Screeners

A study of US airport security screeners revealed:

- Average staff turnover: 126%
- Peak staff turnover: 416%
- Staff wages: ~$6/hr
- Up to 20% of potential threats missed

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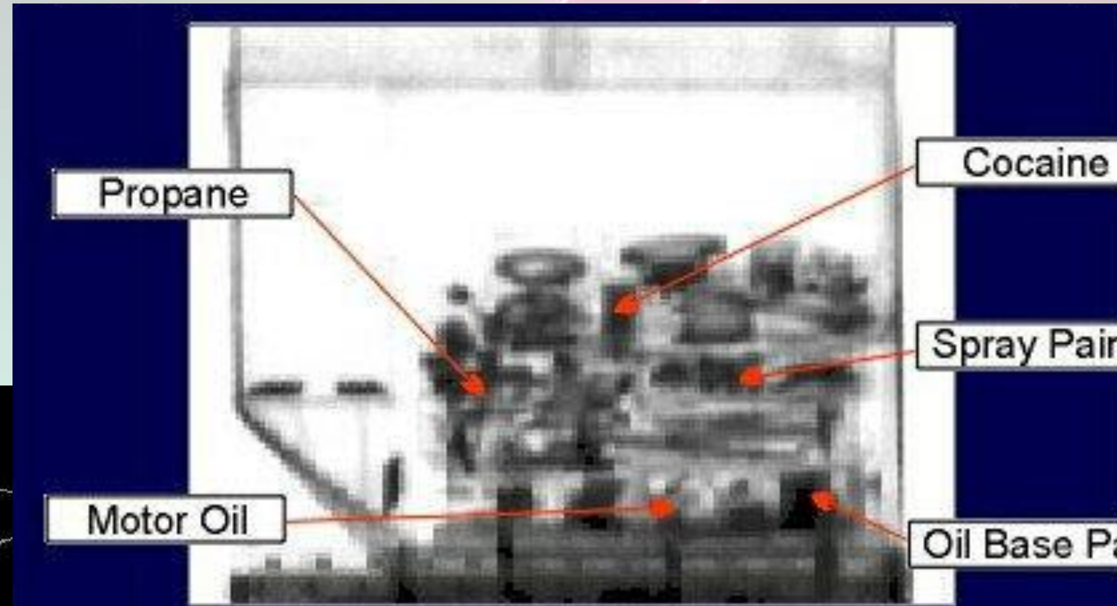
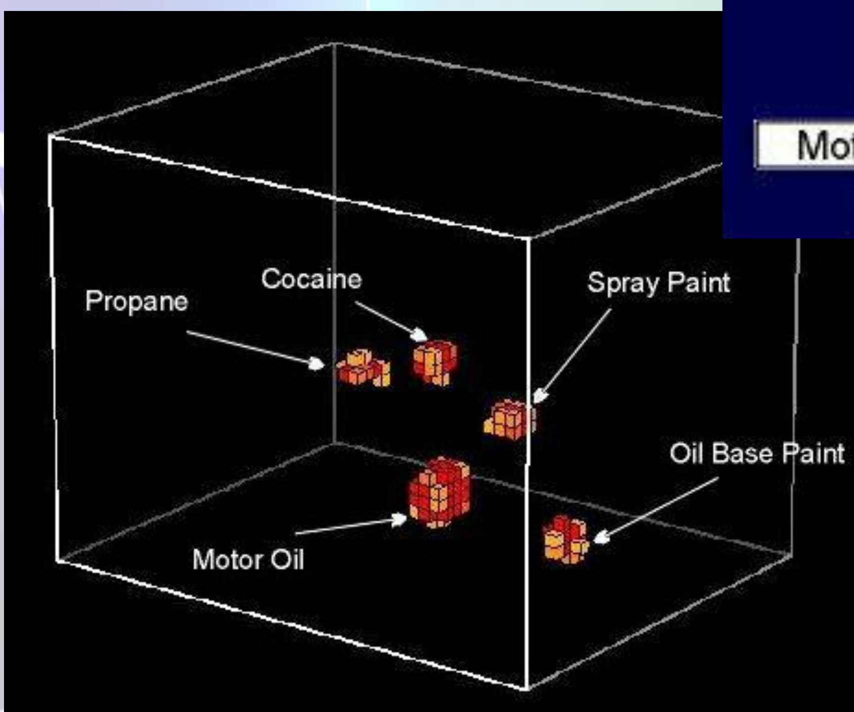
Commercial Pulsed Fast Neutron Analysis (PFNA) Trial

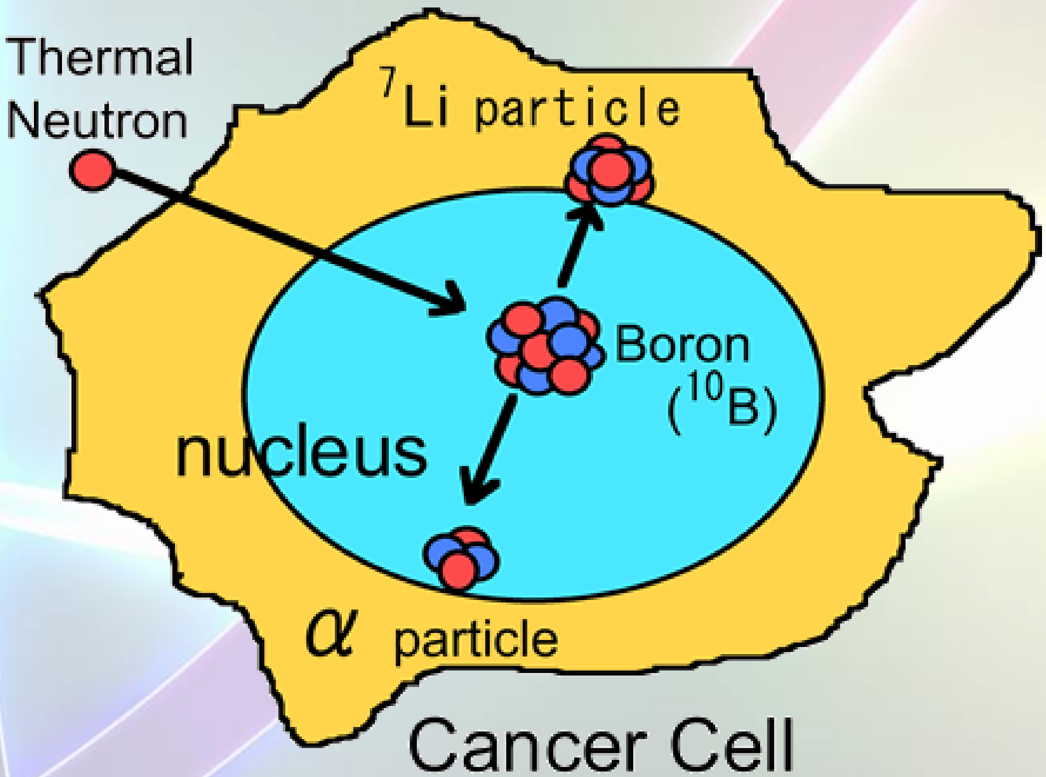
X-Ray image potential threat objects indistinguishable from background



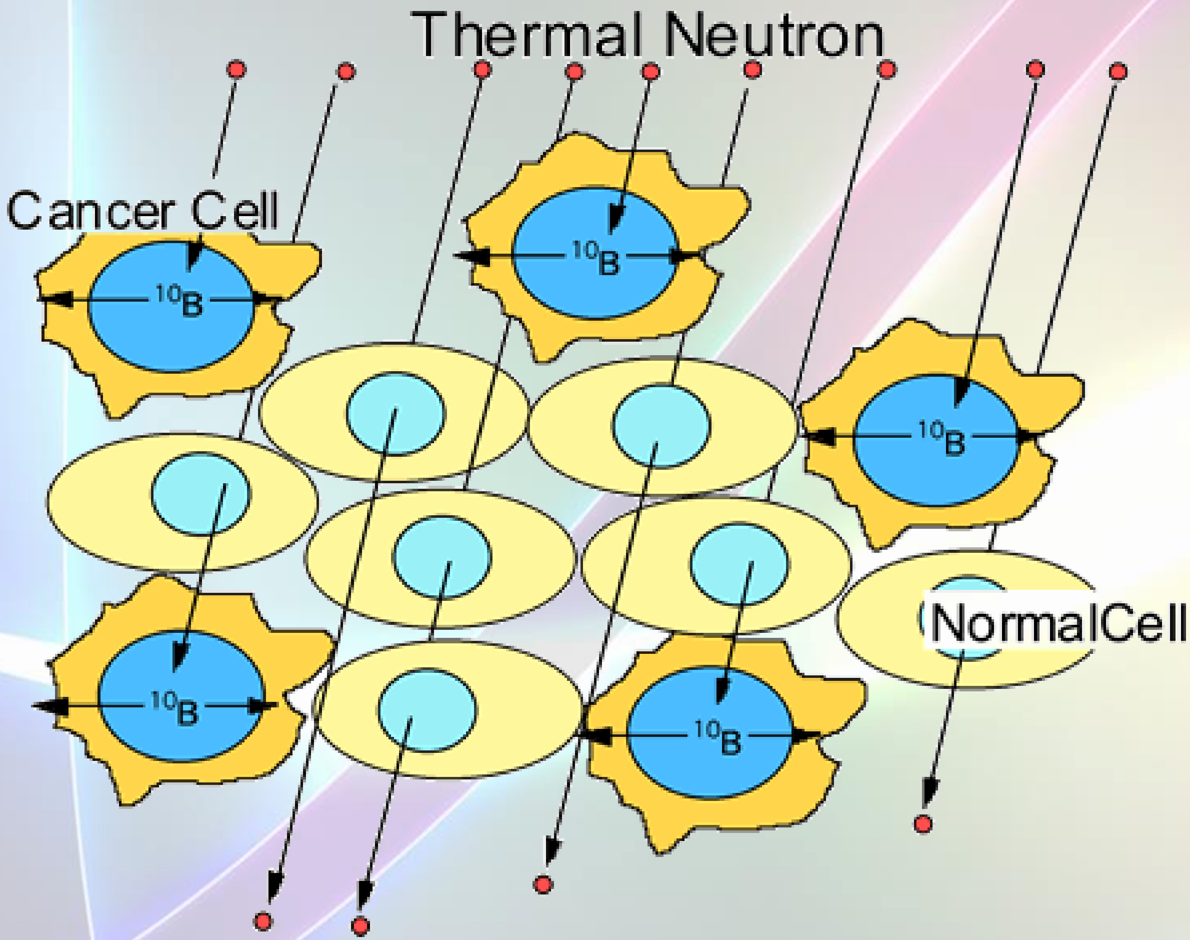


With PFNA threat objects are shown to the operator with background removed

Boron Neutron Capture Therapy (BNCT)



http://www.osaka-med.ac.jp/deps/neu/omcBNCT/BNCT_E/BNCT_E1.html



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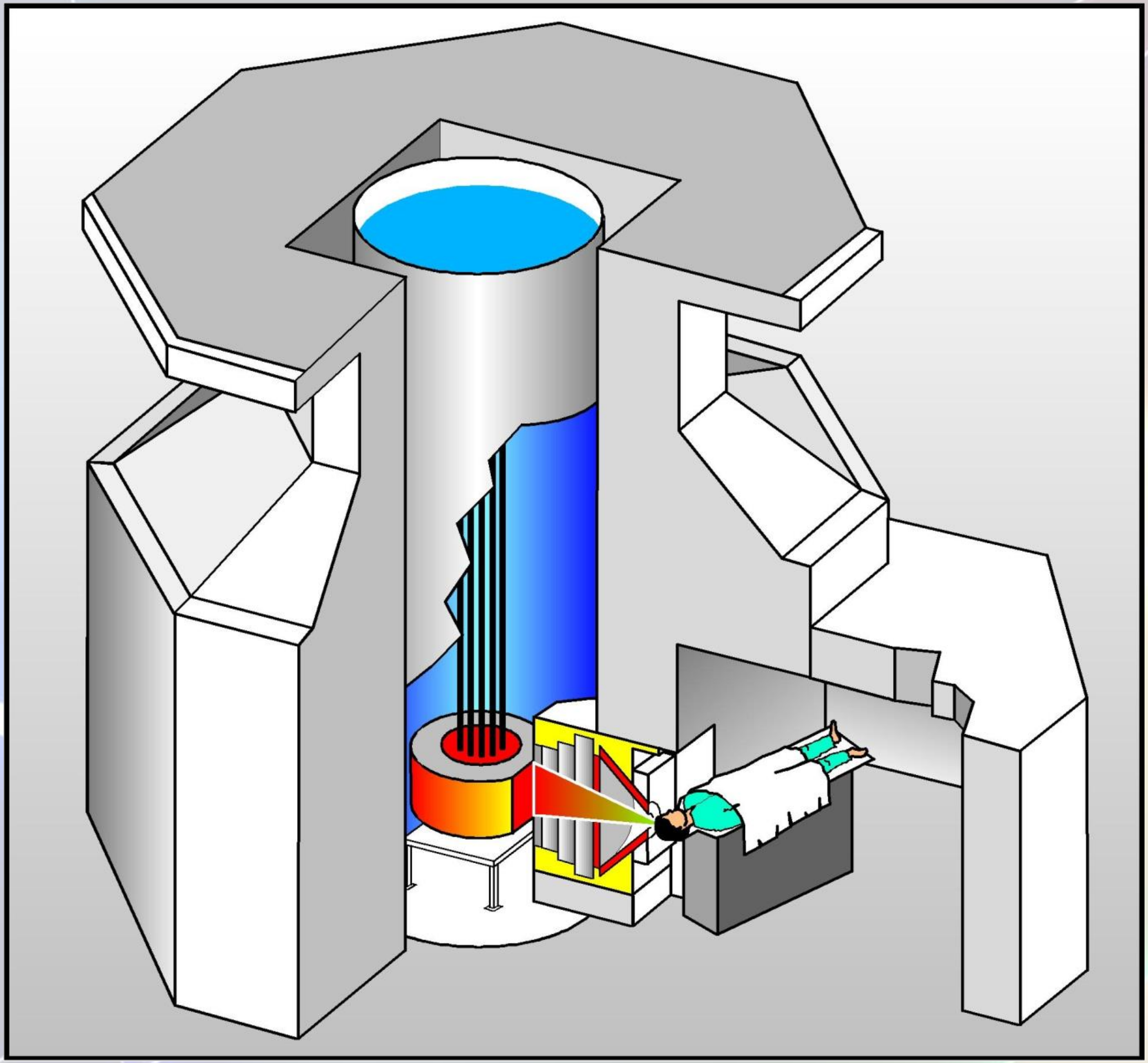

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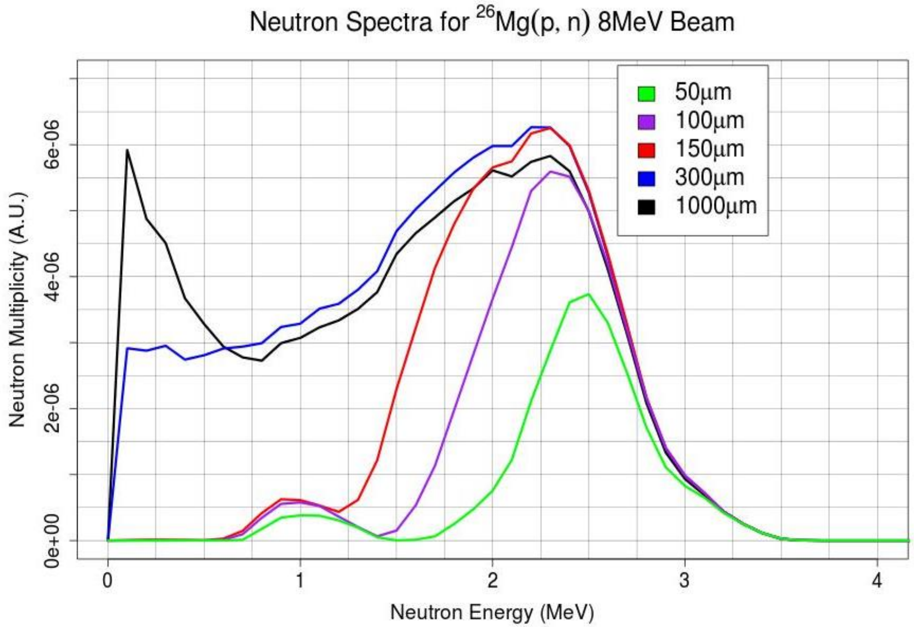
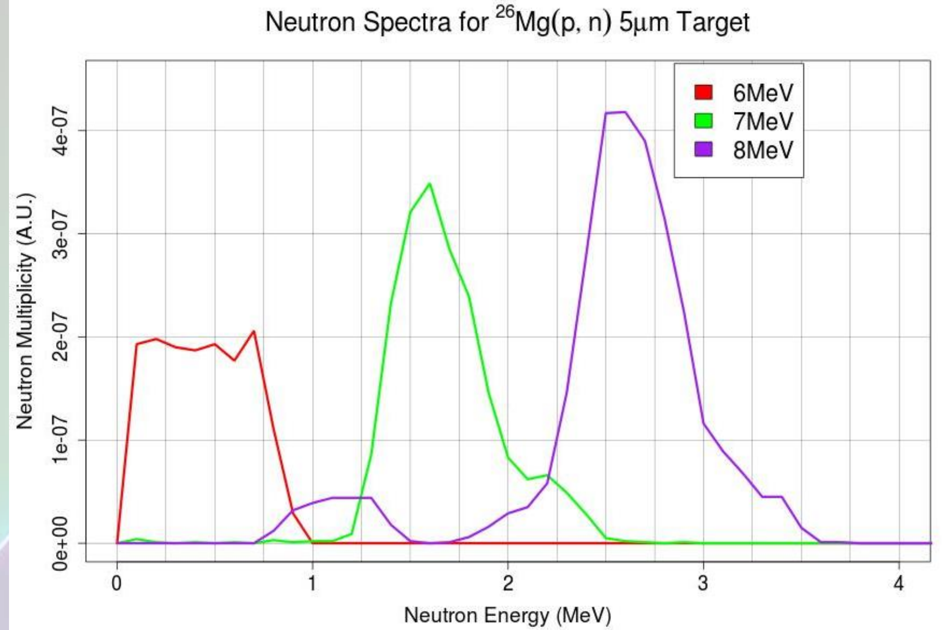
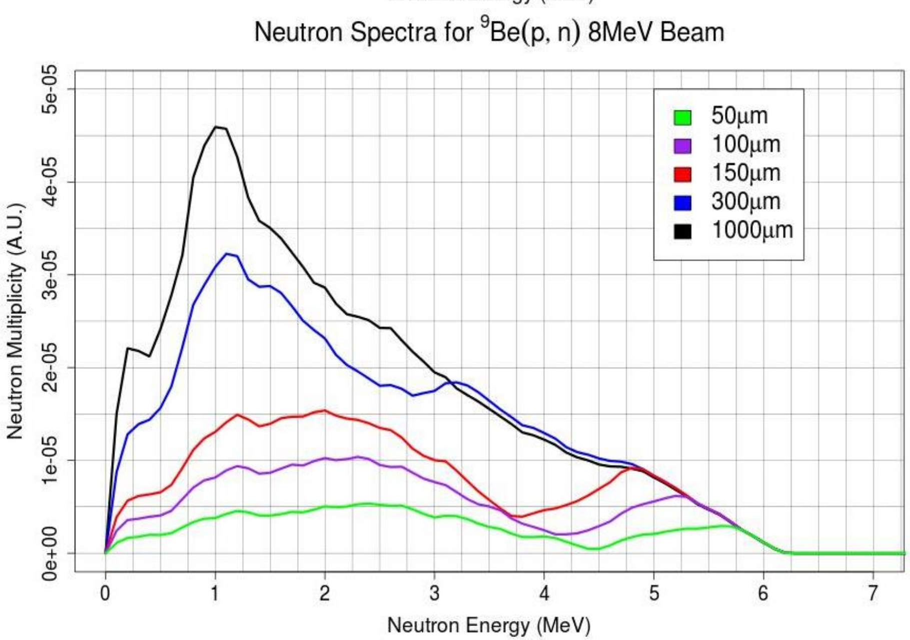
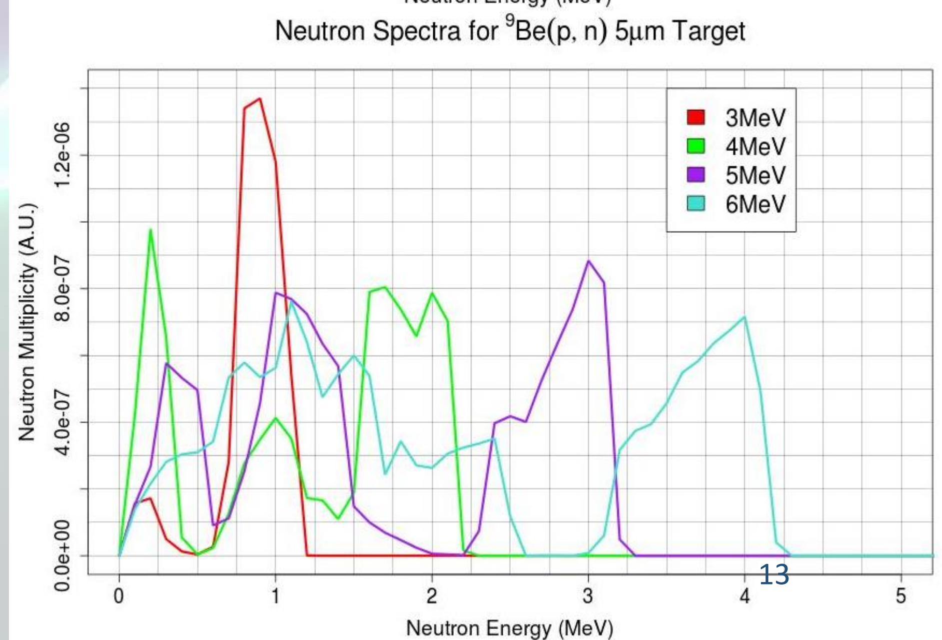
Target Thickness and Beam Energy









Isotope Inventory

“Intended” Reaction

$^{26}Mg(p,n)^{26}Al$

“Alternate” Reaction

$^{26}Mg(p,\alpha)^{23}Na$

Higher Generations

$^{26}Al(p,n)^{26}Si$

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Conclusions

- Numerous applications of neutrons
- Some applications require clean and compact solutions
- Low energy accelerators can provide suitable neutron fluxes

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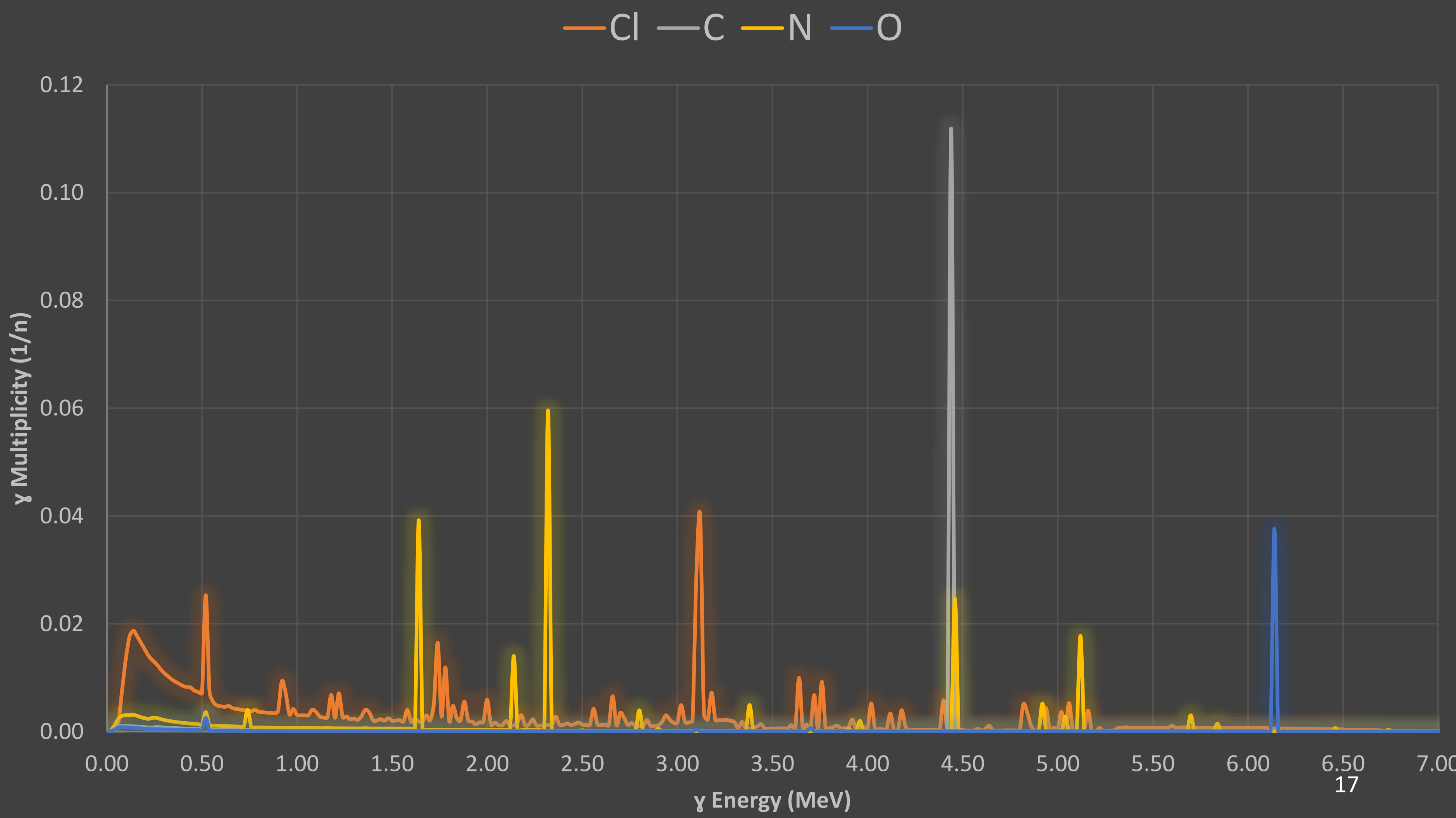
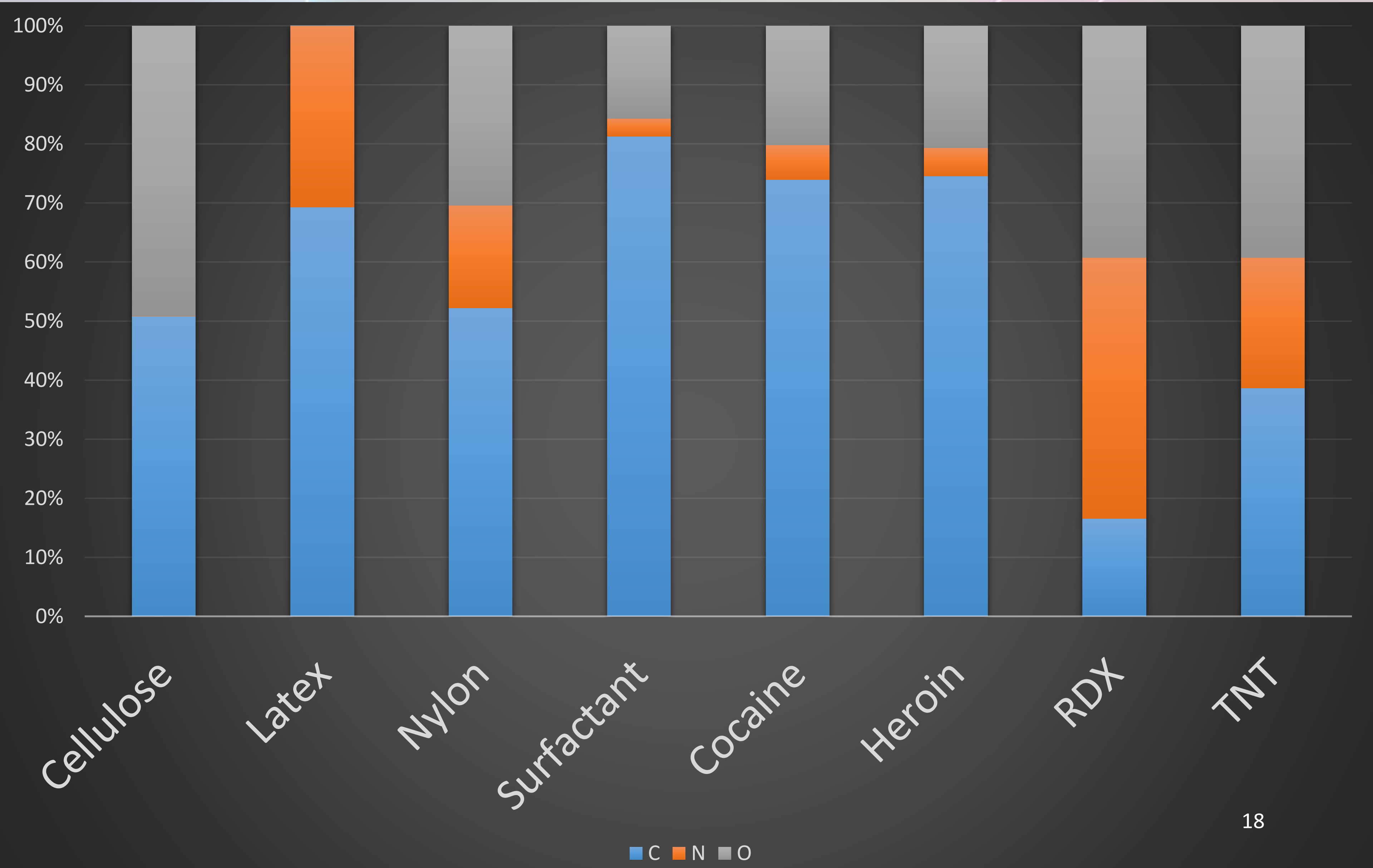
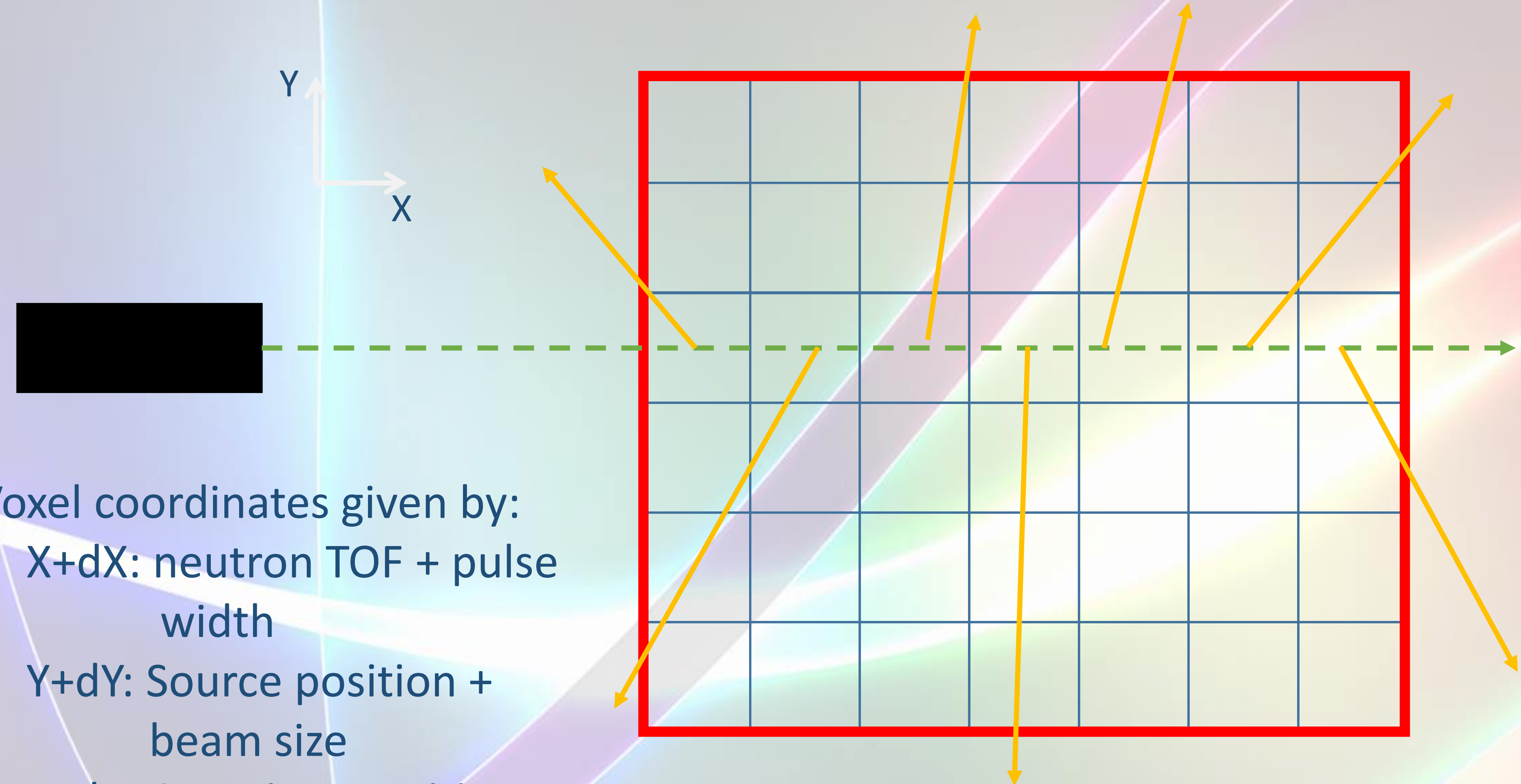
Isotope Dependent Prompt Gamma Spectrum



Element Ratios



Time Of Flight



Voxel coordinates given by:

- X+dX: neutron TOF + pulse width
- Y+dY: Source position + beam size
- Z+dZ: Container position + beam size

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Activation of Cargo

Cargo primarily composed of:

- Repeated irradiation may transmute cargo and lead to activity above background
- Multiple isotope generations
- Common cargo constituents: C, N, O, Al, Ti, Fe, Pb

	C	N	O	Al	Ti	Fe	Pb
Gen. 1:	-	^{14}C (5700yr)	-	^{24}Na (15h) ^{27}Mg (9.5m) ^{28}Al (2.2m)	^{45}Ca (163d) ^{46}Sc (83.8d) ^{47}Sc (3.4d) ^{48}Sc (1.8d)	^{51}Cr (27.7d) ^{53}Mn (3.7Myr) ^{54}Mn (312d) ^{56}Mn (2.6h) ^{57}Mn (1.4m) ^{55}Fe (2.7yr)	^{203}Hg (46.6d) ^{204}Tl (3.8yr) ^{206}Tl (4.2m) ^{207}Tl (4.8m)
Gen. 2+:	^{12}B (0.02s) ^{14}C (5700yr)	^{10}Be (1.6Myr) ^{13}N (10m)	^{14}C (5700yr) ^{16}N (7s) ^{15}O (2m)	^{23}Ne (3.7s) ^{25}Na (59.6s)	^{39}Ar (269yr) ^{42}K (12.4h) ^{43}K (22.2h) ^{44}Sc (4h) ^{45}Ti (3.1h) ^{47}Ca (4.5d)	^{52}Mn (5.6d) ^{53}Fe (8.5s) ^{52}V (3.7m) ^{53}V (1.6m) ^{55}Cr (3.5m) ^{54}Fe (44.5d)	^{205}Pb (15kyr)