



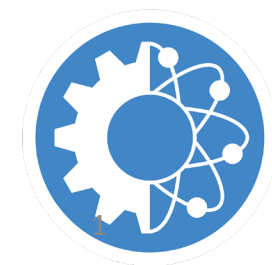
Improving Material Identification Capabilities in Neutron Tomography via Monte Carlo Simulations and Artificial Neural Networks

Christopher Cogliano and Zeyun Wu, *Department of Mechanical and Nuclear Engineering*

ANS Student Conference 2026 | Mathematics, Computation, & AI Applications: III | Texas A&M University

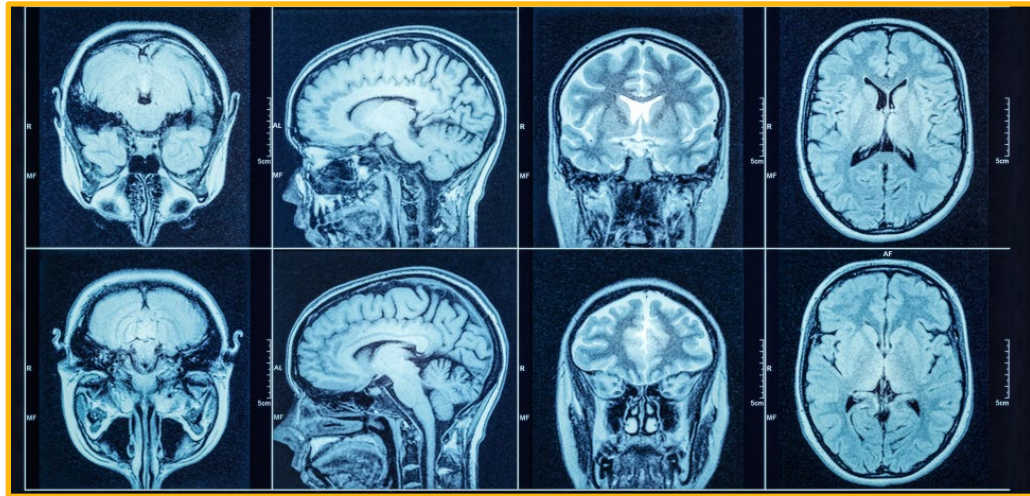


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What is *tomography*?

Tomography: Non-invasive imaging technique that uses penetrating **waves** or **particles** to create cross-sectional “slices” and **3D** images of an object’s internal structure [1]



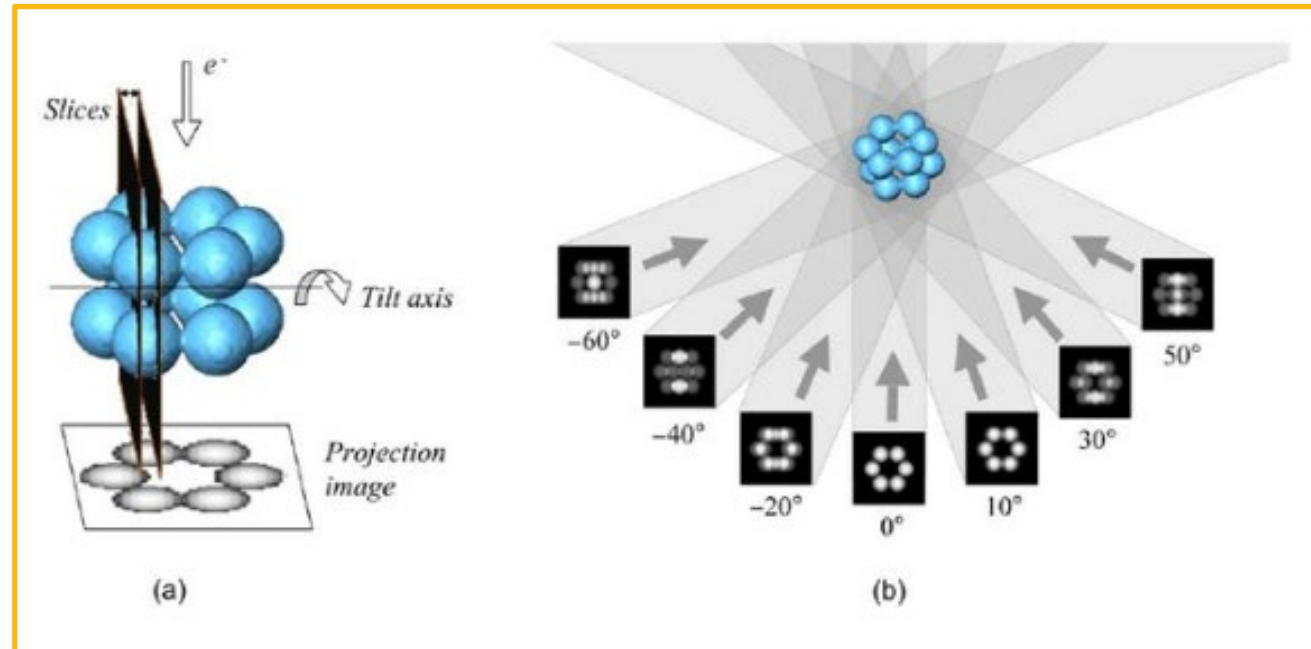
Multiple CT cross-section images of human brain [2]



Neutron CT scan of rotary phone [3]

How are these images made?

Image Reconstruction: Process in which raw **2D radiographic** projection data (taken from various angles) is combined into a 3D image [1]



2D image acquisition and tomographic reconstruction [4]

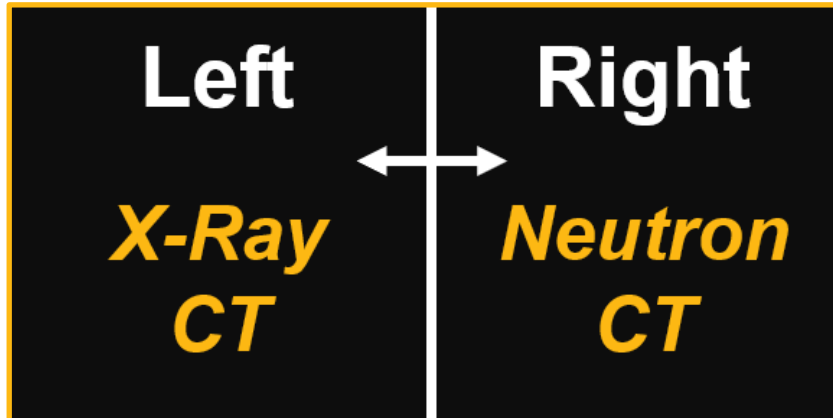
Why with *neutrons*?



Figurine in jar of staples CT image [3]



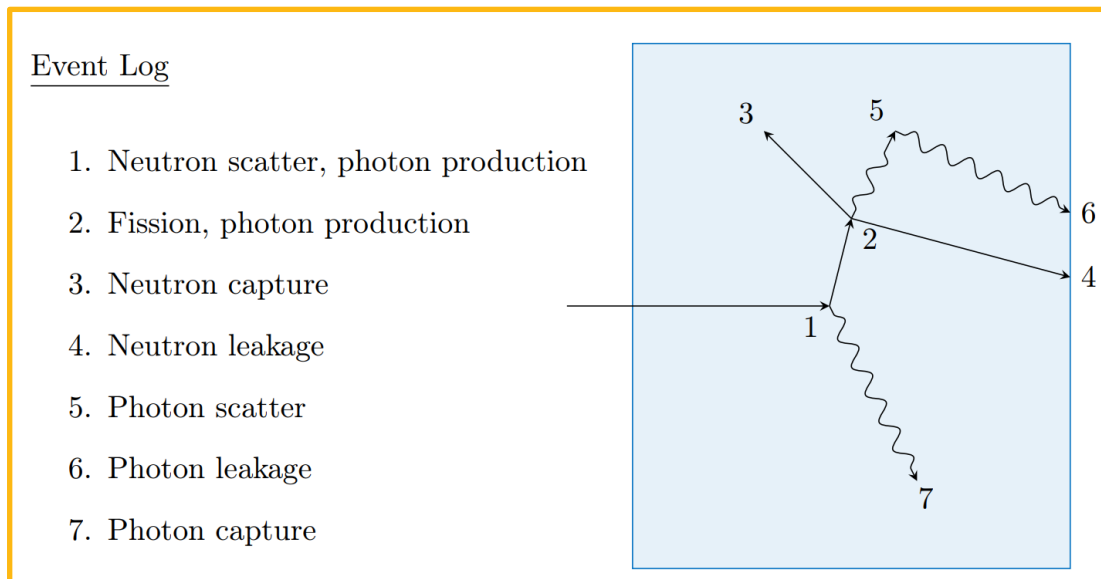
Beretta 92FS CT image [3]



Moving divider line legend

Monte Carlo N-Particle Transport Code (MCNP)

Radiation Transport: Physical process of energy propagation via **particles** through a medium, involving **emission**, **absorption**, and **scattering** [5]



Various particle random walks [5]

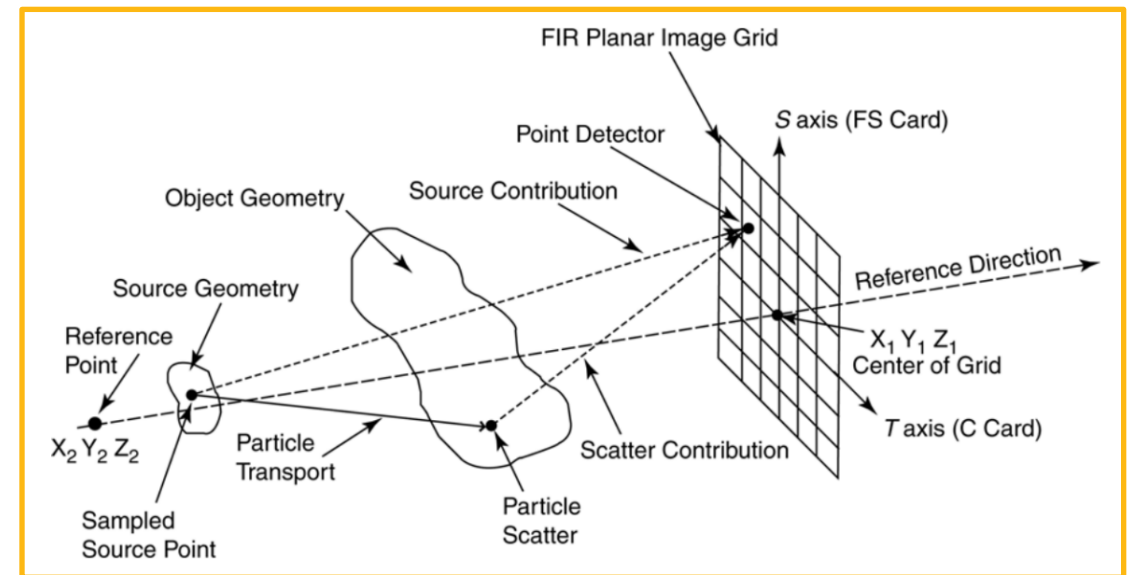


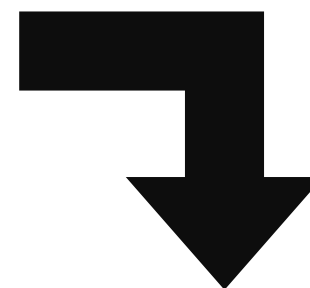
Diagram of a FIR Tally for a source external to object [5]

Flux Image Radiograph (FIR) Tally

$$S_n = \frac{W \cdot p(\Omega_P) \exp(-\lambda)}{L^2}$$

Particle Weight (particles) \rightarrow W
 Probability Density Function for Scattering in Direction Ω_P (unitless) \rightarrow $p(\Omega_P)$
 Mean Free Paths from Particle to Detector (unitless) \rightarrow λ
 Score for Neutron Count Tally (particles/cm²) \rightarrow S_n
 Distance to Detector from Source or Collision Event (cm) \rightarrow L

Estimates



Equation used to estimate neutron flux per FIR pixel [5]

$$1 \text{ sh} = 10^{-8} \text{ s}$$

Unit conversion of shakes to seconds [5]

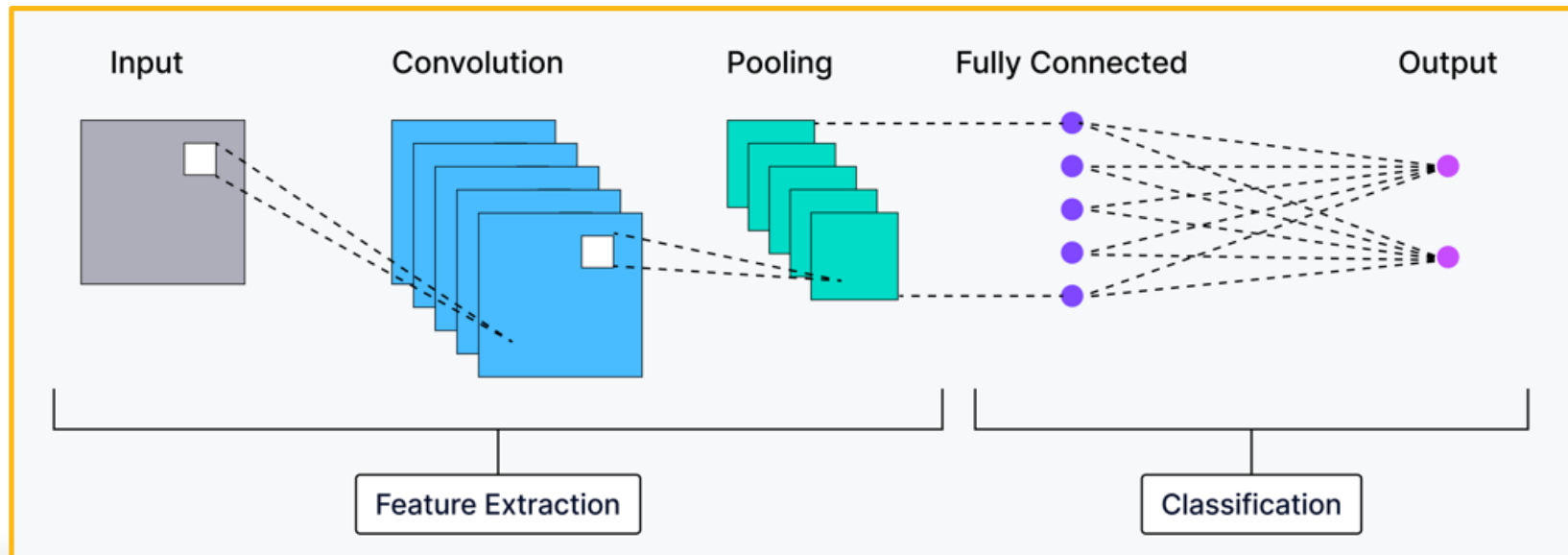
$$\phi_P = \int dE \int dt \int d\Omega \psi(\mathbf{r}_P, \boldsymbol{\Omega}, E, t)$$

Point Neutron Flux (particles/cm²) \rightarrow ϕ_P
 Energy (MeV) \rightarrow dE
 Time (sh) \rightarrow dt
 Solid Angle (sr) \rightarrow $d\Omega$
 Angular Flux (particles/cm²/sh/MeV/sr) \rightarrow ψ
 Neutron Position Vector (cm) \rightarrow \mathbf{r}_P
 Direction Unit Vector (unitless) \rightarrow $\boldsymbol{\Omega}$

Estimated neutron flux per FIR pixel [5]

Artificial Neural Networks (**ANNs**)

ANN: Computational model inspired by the human brain that uses interconnected layers of nodes (artificial neurons) to **process data, learn patterns, and make decisions** [6]



Architecture of convolutional neural networks (CNNs) [7]

Generalized Model

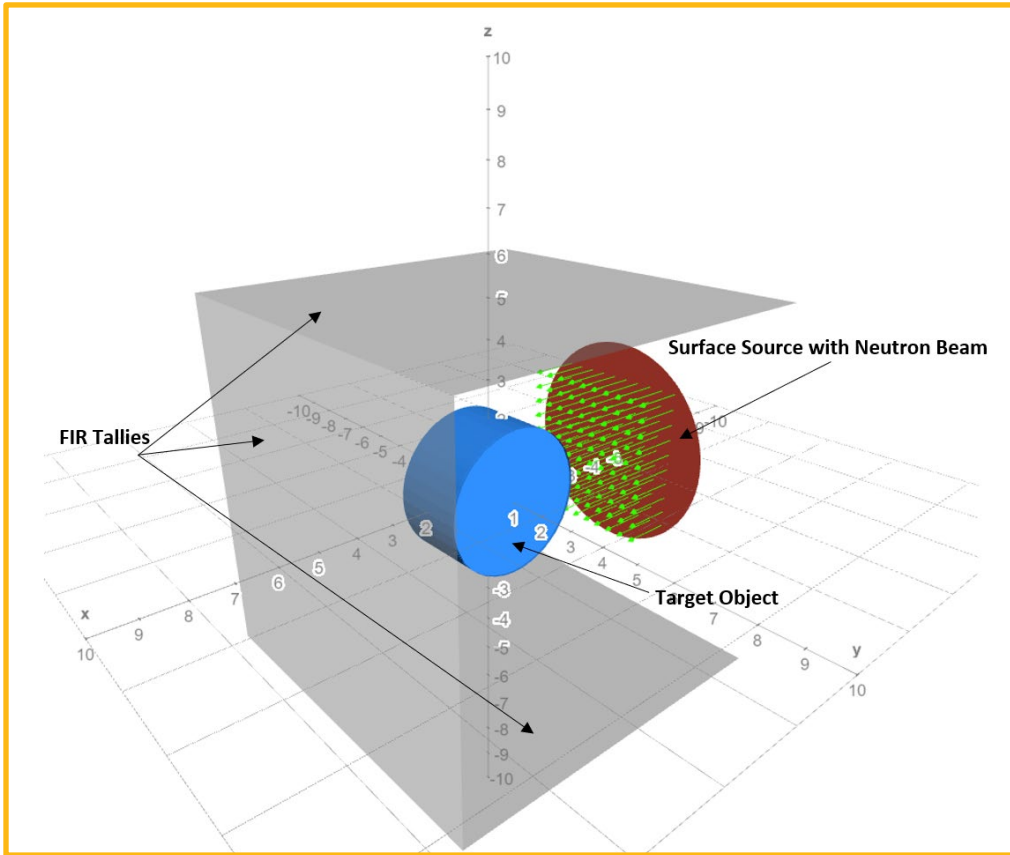


Diagram of the MCNP model geometry for $\theta = 0^\circ$

Cf²⁵² Spontaneous Fission (SF) Parameters [8]

Constant	Value	Unit
a	1.18	MeV
b	1.0342	MeV ⁻¹
C	0.63802	Unitless



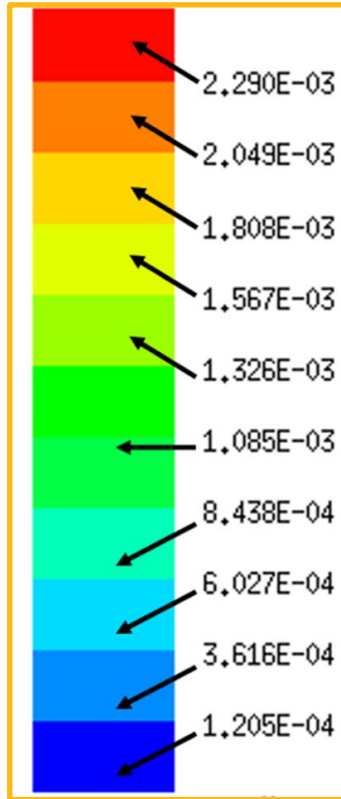
$$p(E) = C \exp(-E/a) \sinh(\sqrt{bE})$$

Energy sampling probability function

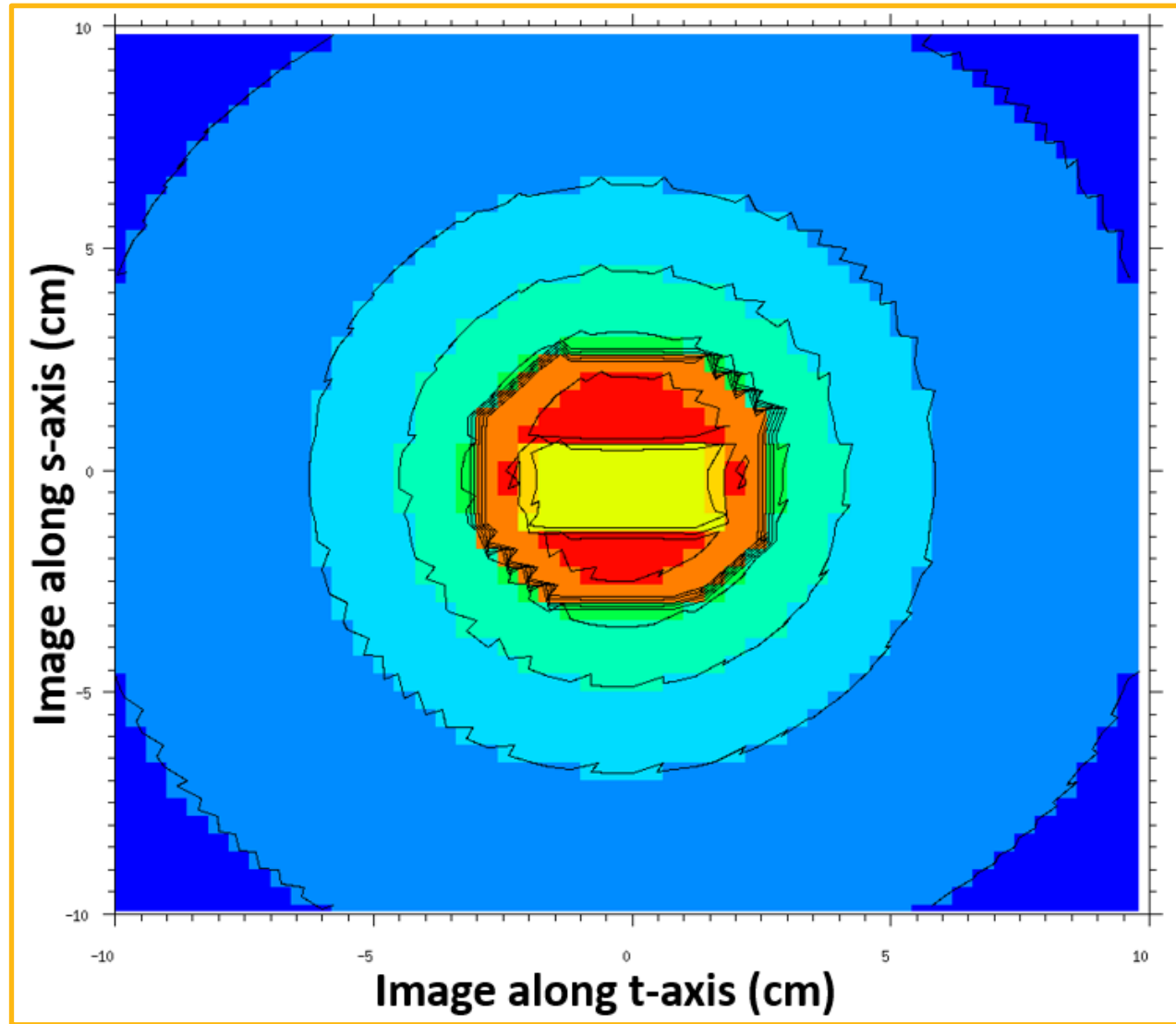
Sampled energy value (MeV)

Watt fission spectrum energy sampling equation [5]

Results



Pixel color legend for 2D image



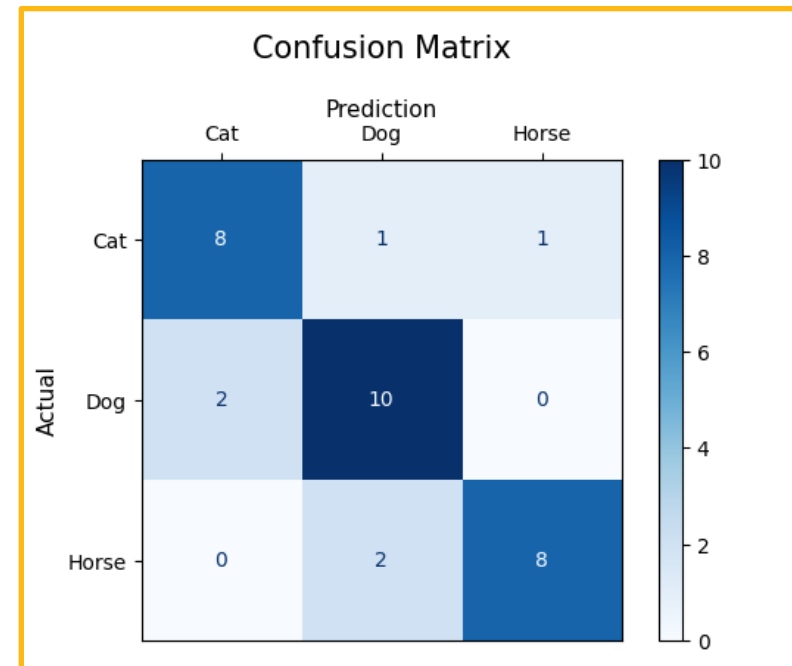
2D image of light water cylinder produced by front neutron FIR tally

Work in Progress

Inverse Transport Analysis: The **reconstruction** and **identification** of internal optical, radiative, or **material** properties of a medium by analyzing particles exiting its boundaries [9]



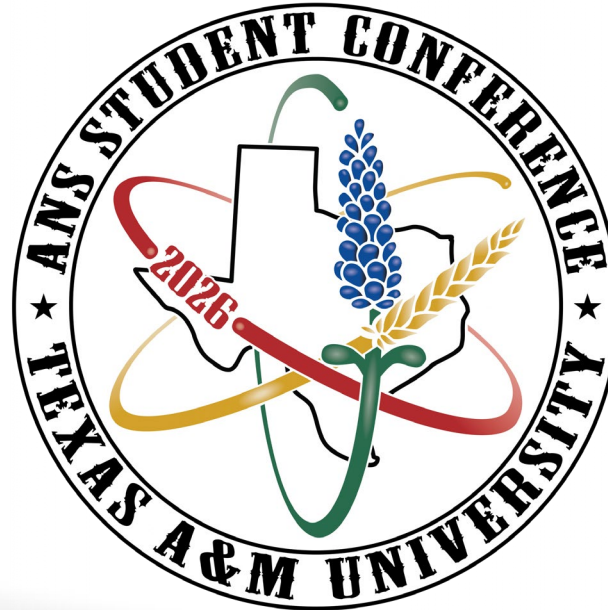
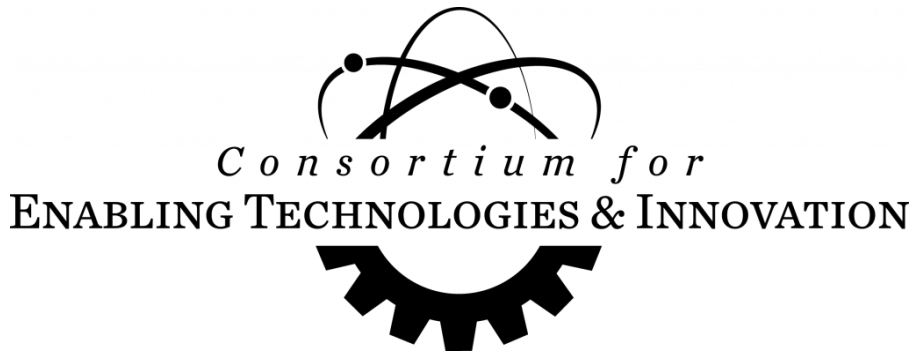
Keras application programming interface (API) logo [10]



Simplified CNN confusion matrix example [11]

Acknowledgements

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Thank You!

Questions?

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