



serco

Serco Assurance

## Applications of MCBEND

Presentation to  
**NPL Workshop on Monte Carlo  
codes**

by  
**Pat Cowan**

**The ANSWERS Software Service  
Serco Assurance**

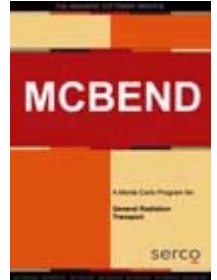
# Overview

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- The MCBEND Code
- Traditional Applications
- Industrial Applications
- Design of Shielded Facilities
  - ◆ Food Irradiation Chamber
  - ◆ Hospital Treatment Room
- Operational Analysis
  - ◆ Food Irradiation
  - ◆ BNCT Treatment Planning
  - ◆ Irradiator Decommissioning
  - ◆ Oil Well Logging
- Summary

# MCBEND

- MCBEND is a Monte Carlo code
- Monte Carlo Method
  - ◆ Physically-realistic simulation of the fate of individual particles
  - ◆ Predicts the level of nuclear radiation in a detailed geometric system in space, energy and time
- Outcome is often some form of radiation flux map
  - ◆ radiation dose
  - ◆ radiation effects - damage/heating
  - ◆ instrument response



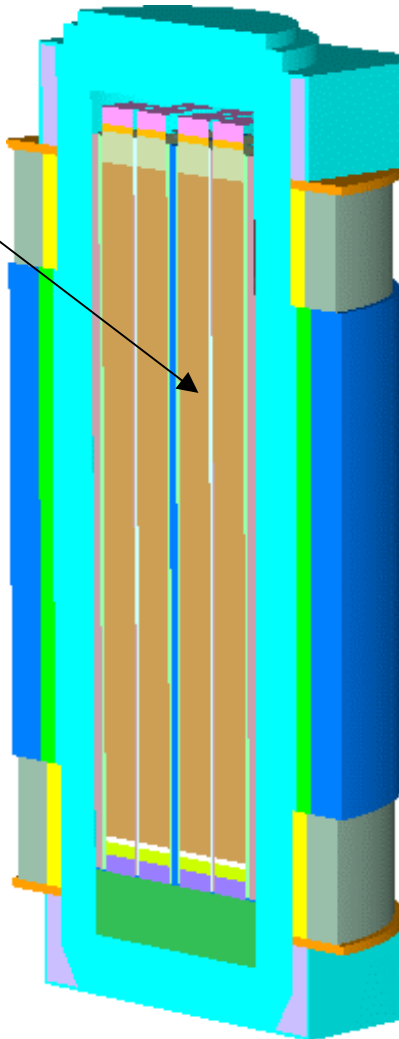
# Traditional Applications of MCBEND

- MCBEND has many years of successful application in the nuclear industry:
  - ◆ Reactor operations
  - ◆ Fuel transport
  - ◆ Storage facilities
  - ◆ Reprocessing plant
  - ◆ Waste handling facilities
  - ◆ Incident detection systems
  - ◆ Materials degradation
  - ◆ Personnel dose uptake
  - ◆ Evacuation dose contours



# Typical Nuclear Industry Shielding Problem

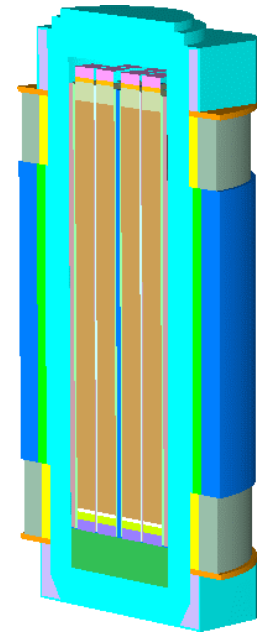
Source of Radiation



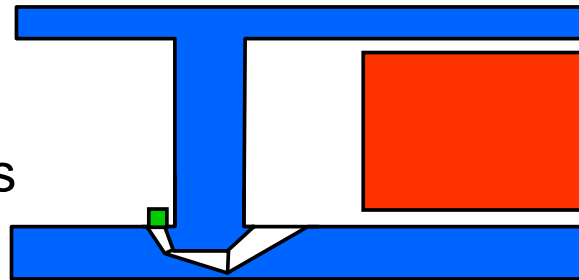
- Design of Radiological Shield
- Determination of external dose-rates

# Problems facing Shielding Assessors

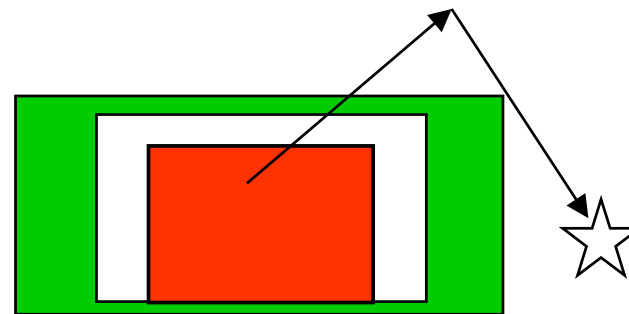
- Dealing with bulk penetration
- Identifying shield weaknesses



- Streaming
  - ◆ Ducts, labyrinths

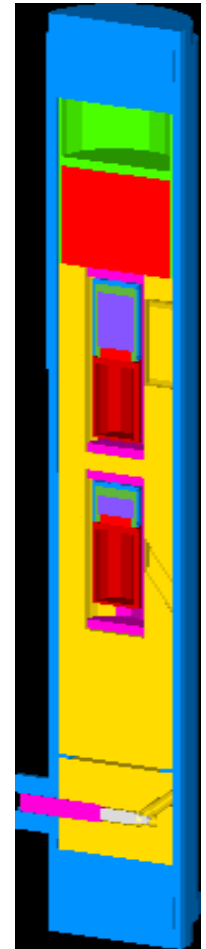
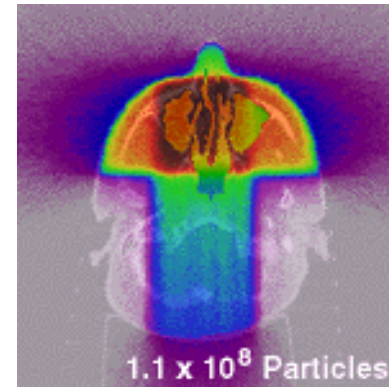


- Skyshine
  - ◆ Cask parks
  - ◆ Flask transport
  - ◆ Waste facilities



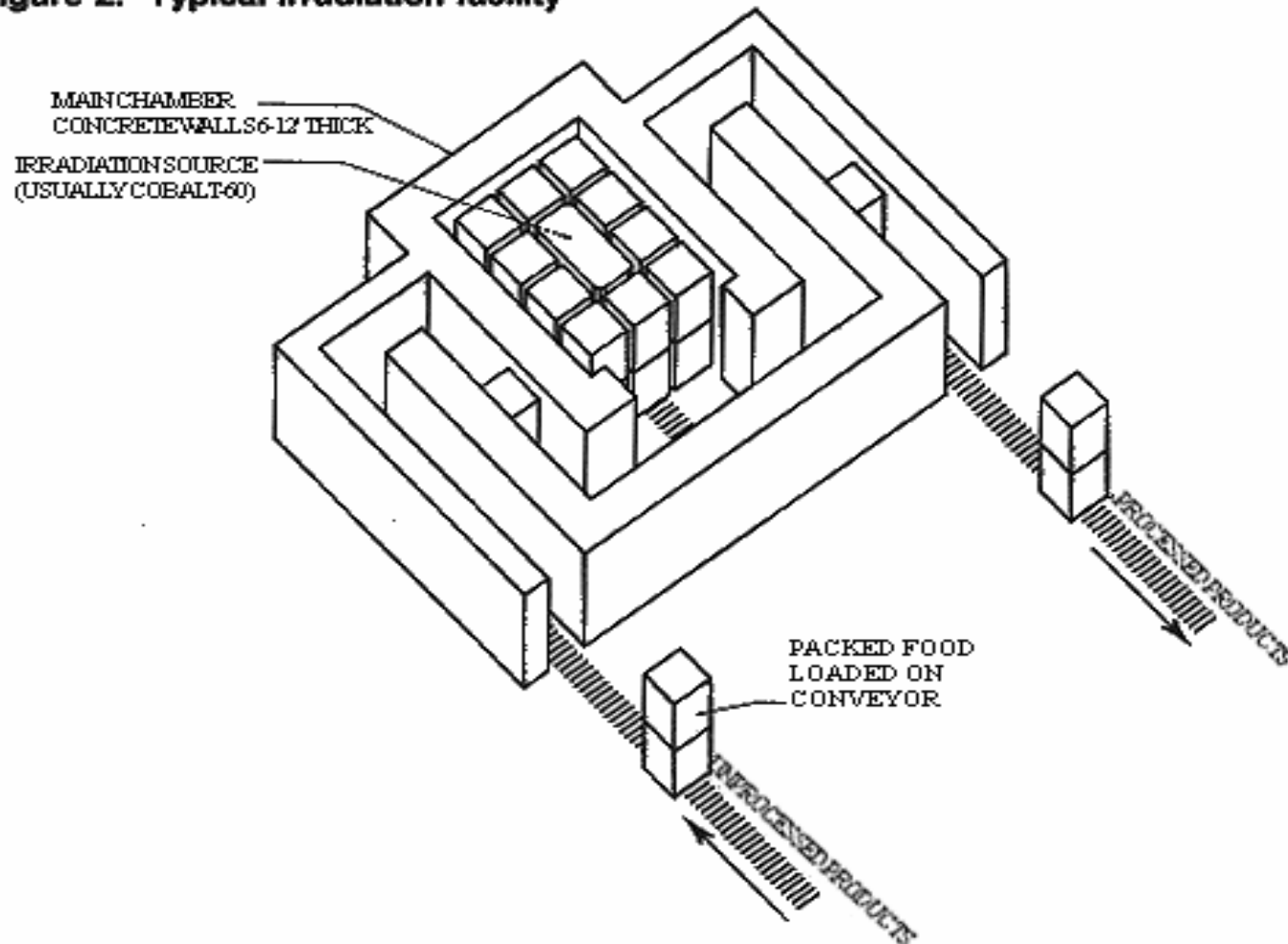
# Industrial Applications of MCBEND

- **Design of Shielded Facilities**
  - ◆ Food Irradiation Chamber
  - ◆ Hospital Treatment Room
  - ◆ Source Calibration Facility
- **Operational Analysis**
  - ◆ Dose Uptake in Food
  - ◆ BNCT Treatment Planning
  - ◆ Irradiator Decommissioning
  - ◆ Nuclear Oil Well Logging Tools



# Design of Shielded Facilities

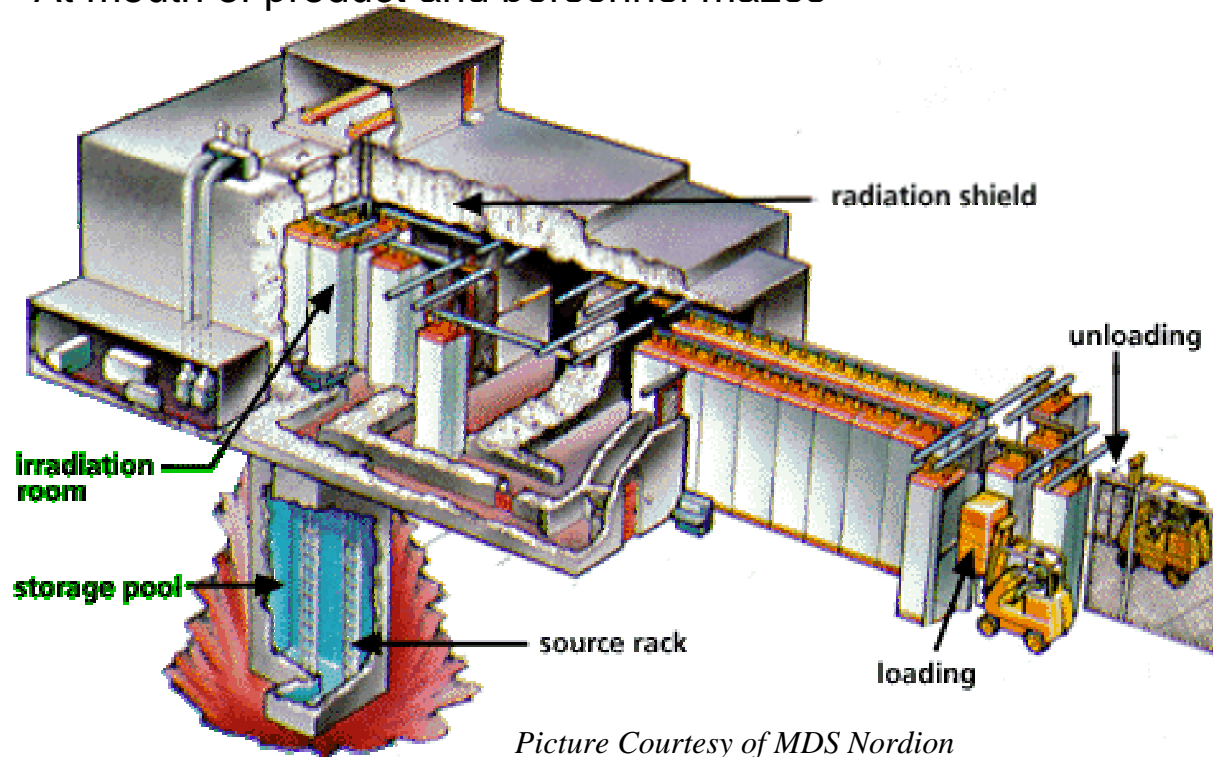
**Figure 2. Typical irradiation facility**



Source: Radiation Technology, Inc., Rockaway, NJ. Adapted FDA Consumer, July/August 1986, p. 14-15.

# Food Irradiation Chamber

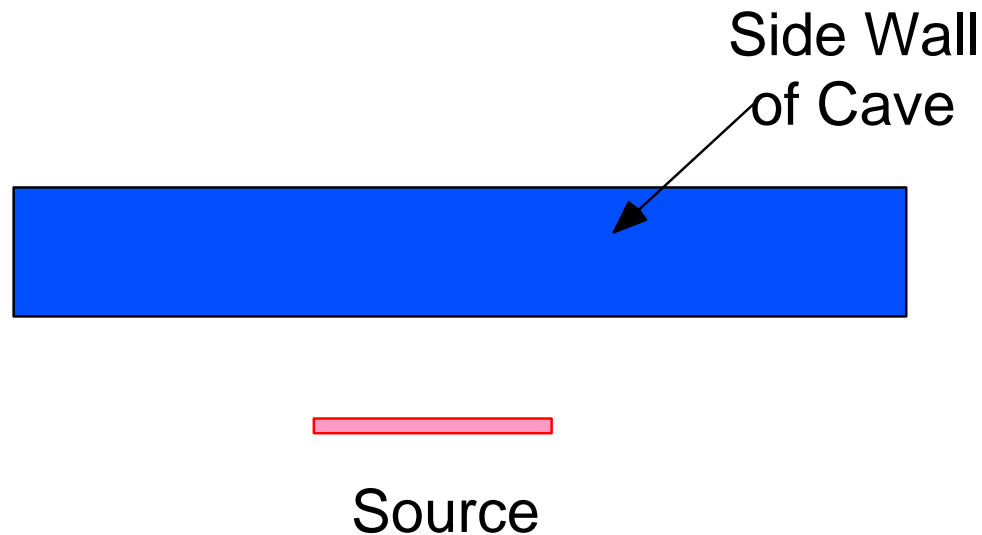
- Food is irradiated by large gamma-ray sources in a heavily shielded cave, to kill off bacteria and preserve it
- MCBEND was used to determine personnel dose-rates outside the chamber:
  - ◆ Through the bulk shielding
  - ◆ At mouth of product and personnel mazes



*Picture Courtesy of MDS Nordion*

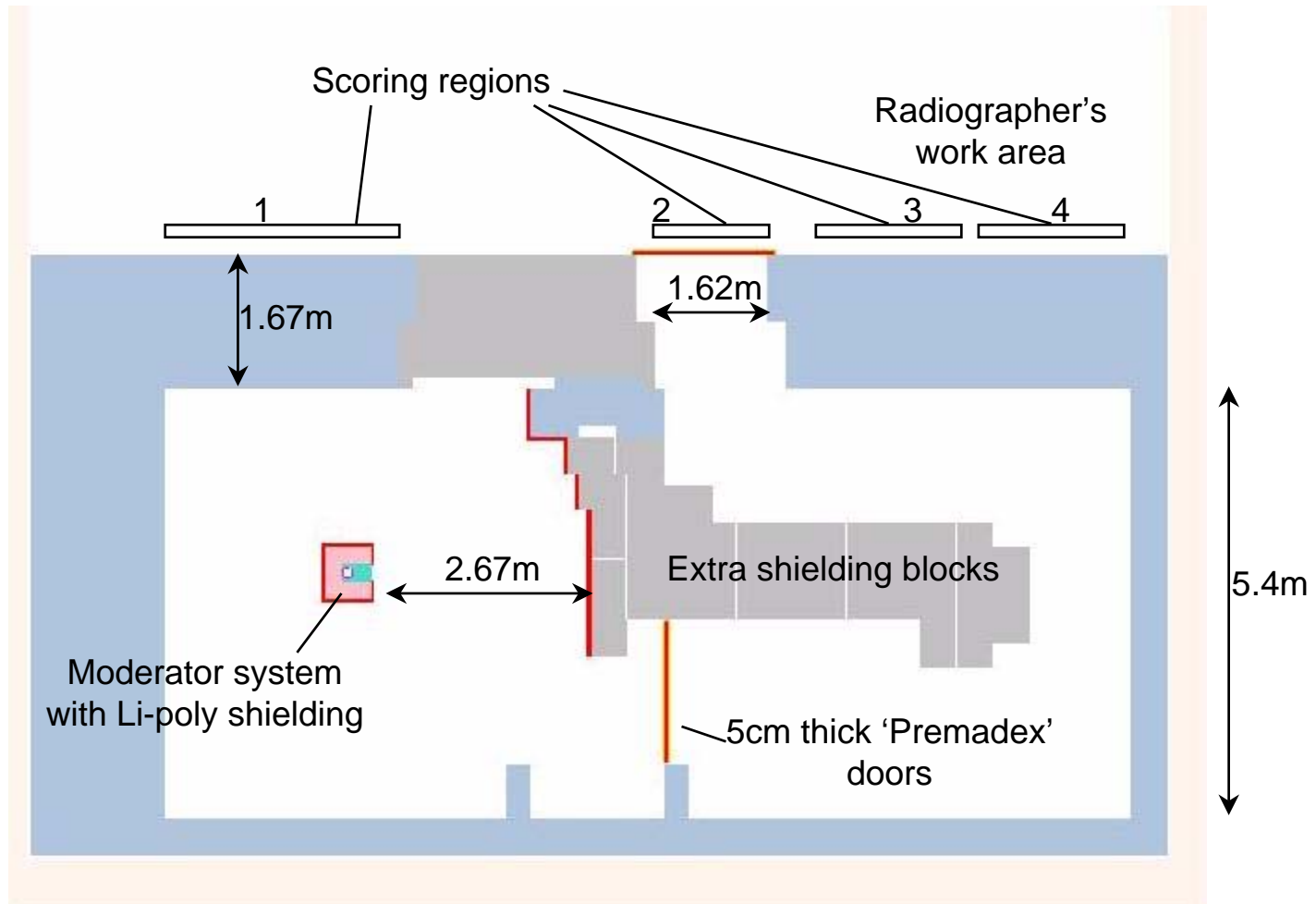
# Food Irradiation Chamber

- MCBEND was also used to determine the temperature profile in cave walls
  - ◆ The walls of the chamber were divided up into layers.
  - ◆ The energy deposited in each layer by the gamma radiation was determined using MCBEND
  - ◆ Heat transfer calculations were performed using the TAU Finite Element code, assuming natural cooling



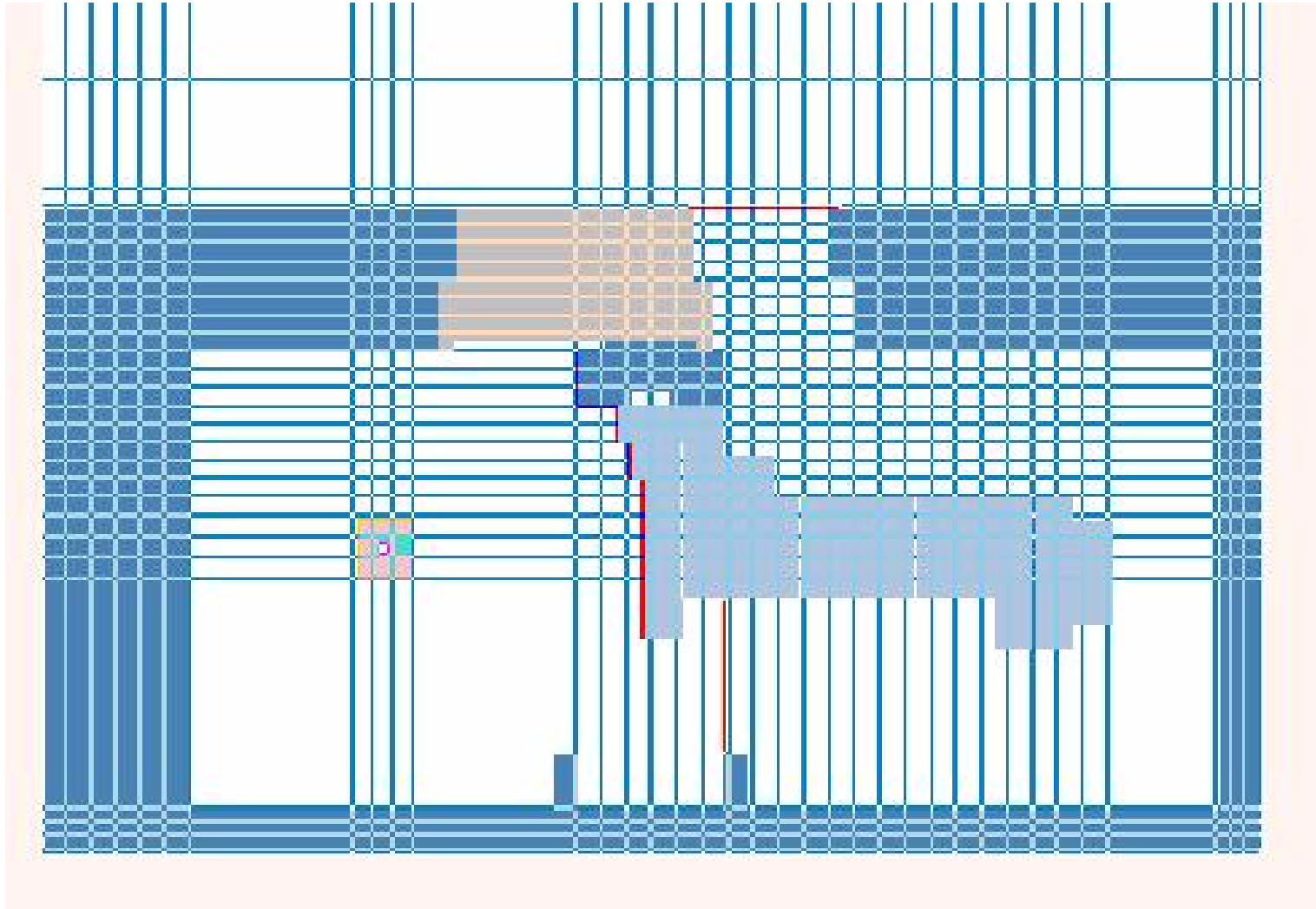
# Hospital Treatment Room

Assessment carried out by Birmingham University



# Hospital Treatment Room

MCBEND model of Shielding Labyrinth showing Splitting Mesh



# Hospital Treatment Room

## Sample of MCBEND Results

No extra shielding - neutron dose

Scoring region	Dose rate ( $\mu\text{Sv/hr/mA}$ )	% statistical error
2 (doorway)	65.5	7.4
3 (radiographer's area)	3.60	7.6

Li-polyethylene shielding around moderator system - neutron dose

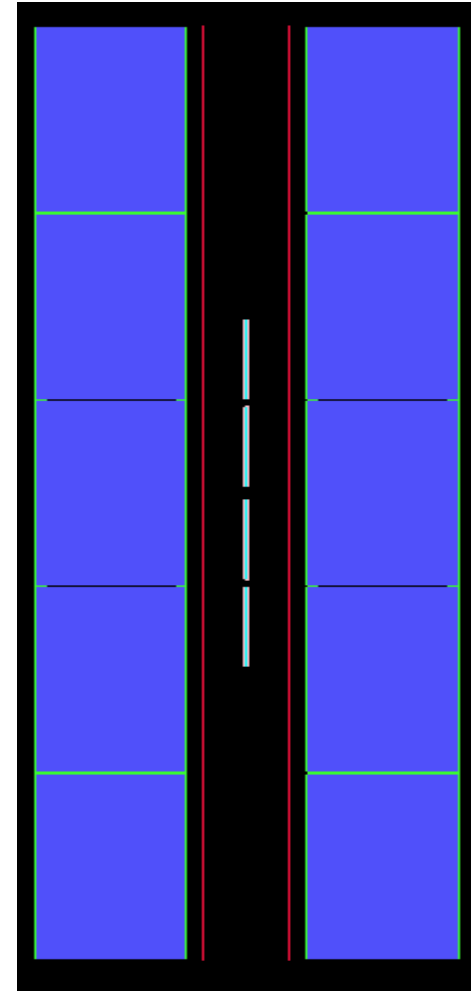
Scoring region	Dose rate ( $\mu\text{Sv/hr/mA}$ )	% statistical error
2 (doorway)	17.7	6.9
3 (radiographer's area)	1.02	7.1

Li-polyethylene shielding around moderator system  
and 'Premadex' screens at both ends of labyrinth - neutron dose

Scoring region	Dose rate ( $\mu\text{Sv/hr/mA}$ )	% statistical error
2 (doorway)	0.294	4.1
3 (radiographer's area)	0.046	4.0

# Operational Analysis – Food Irradiation

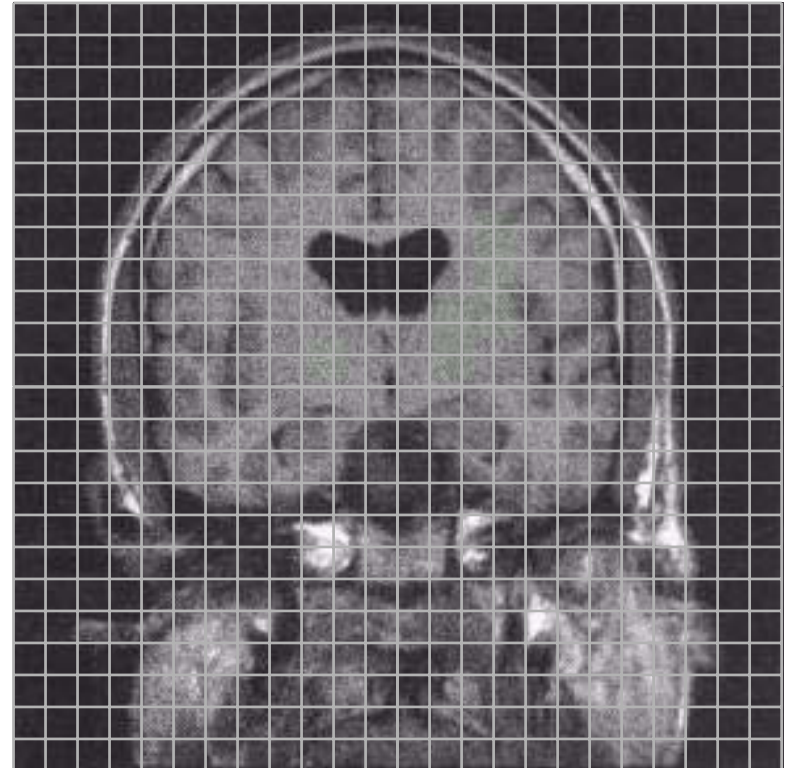
- MCBEND was used to determine the Dose Uptake by Product
  - ◆ In the MCBEND model the whole 'product' was divided into a number of segments.
  - ◆ Dose Uptake was determined in every segment to see the variation in dose uptake for a number of source designs.
  - ◆ Optimum source design is when all segments of the product are evenly irradiated.



# Operational Analysis – BNCT Treatment Planning

Feasibility Study carried out by Birmingham University

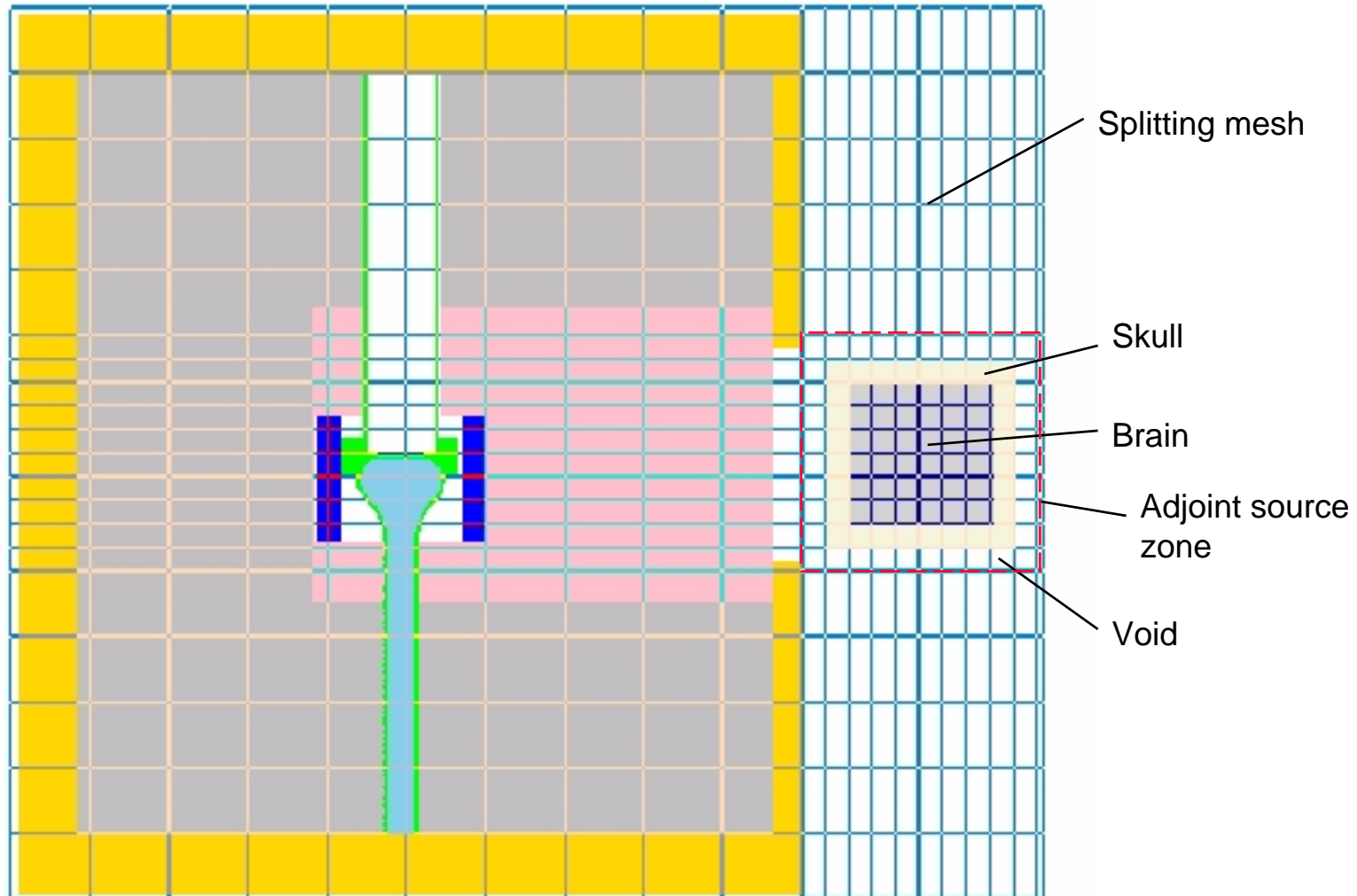
- CT scan of patient
- Overlay 3D mesh
- Volume-weighted assignment of materials to each 3D mesh element (e.g. brain, bone, scalp, void)
- Put 3D array into MCBEND
- Calculate 3D distribution of dose rates for each dose component
- Overlay 3D dose distribution onto CT scan



# Operational Analysis – BNCT Treatment Planning

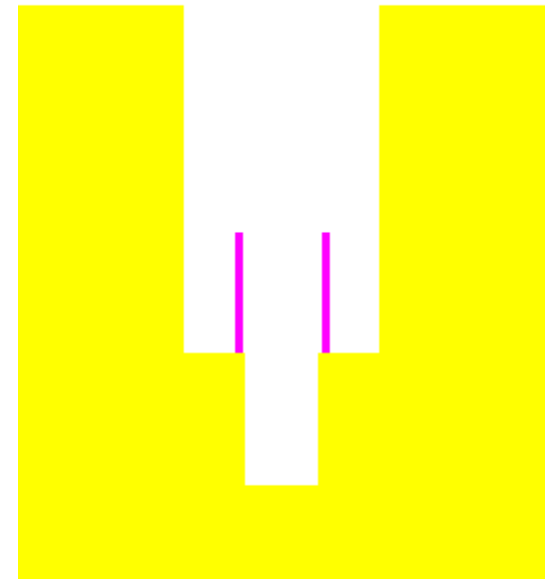
Feasibility Study carried out by Birmingham University

**Phantom model**  
10x10x10 array  
of 20mm voxels  
  
or 20x20x20 array  
of 10mm voxels  
  
**Splitting/Scoring  
Mesh**  
10x10x10 array  
of 20mm voxels



# Operational Analysis – Irradiator Decommissioning

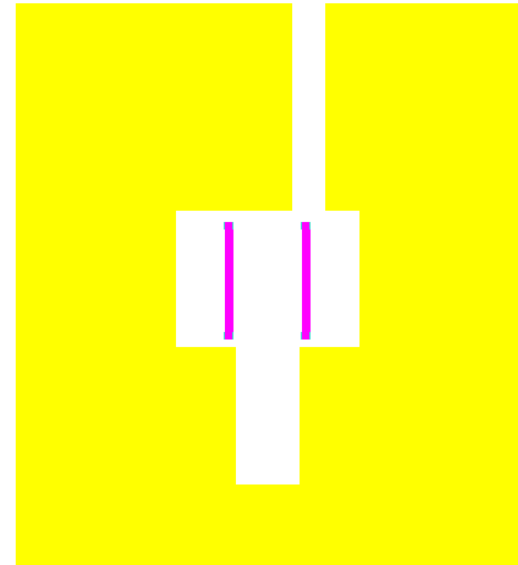
- MCBEND was used to determine gamma-ray dose-rates during decommissioning of a Hospital Irradiator.
  - ◆ Dose-rates were calculated all around the vicinity of the irradiator containing the sources, with the irradiator lid raised (or completely removed) during source removal operations.
  - ◆ Dose-rates were calculated in the room directly above the room in which the irradiator was housed.



# Operational Analysis – Irradiator Decommissioning

## ■ MCBEND Results

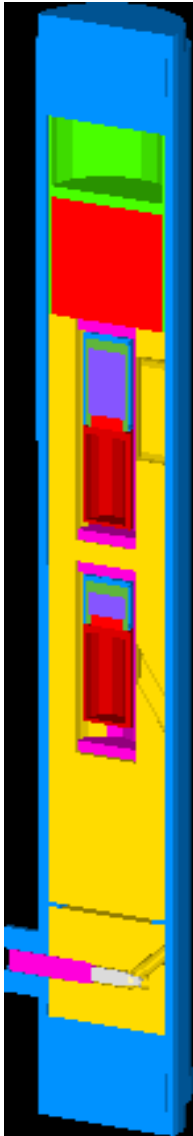
- ◆ Calculations were performed both with and without temporary steel or lead shield plugs located in the top of the irradiator.
- ◆ The optimum design of temporary shield plug was determined, which gave acceptable dose-rates while allowing access to the sources individually for removal.



# Operational Analysis - Oil Well Logging

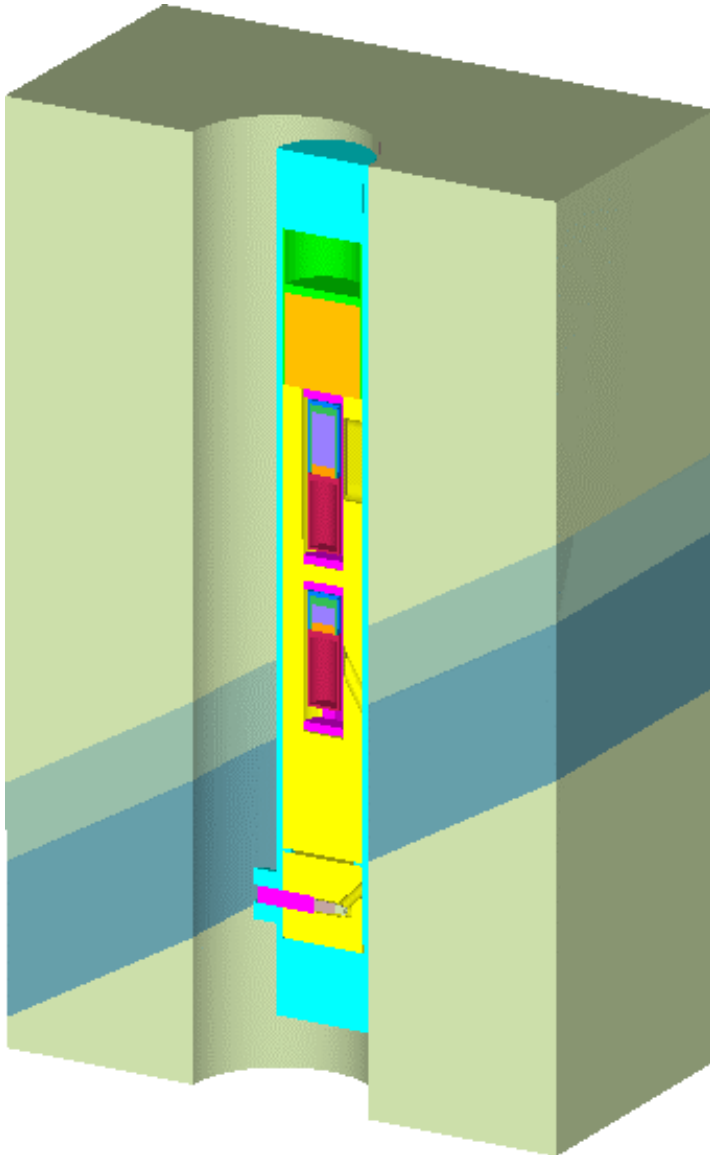
- Oil Well Logging tools are instruments lowered into boreholes, which are used to locate oil.
- As the tool is moved up the borehole, it takes measurements from the surrounding rock formation - which are recorded.
- Even after a well is producing oil, Oil companies may want to log the well to see how the formation properties have changed to give them information on how much oil is left.
- MCBEND has been used to model various types of Nuclear Logging Tools:
  - ◆ Gamma Density tools
  - ◆ Neutron Porosity tools
  - ◆ Pulsed Neutron Capture or Carbon/Oxygen tools

# Gamma Density Logging Tool



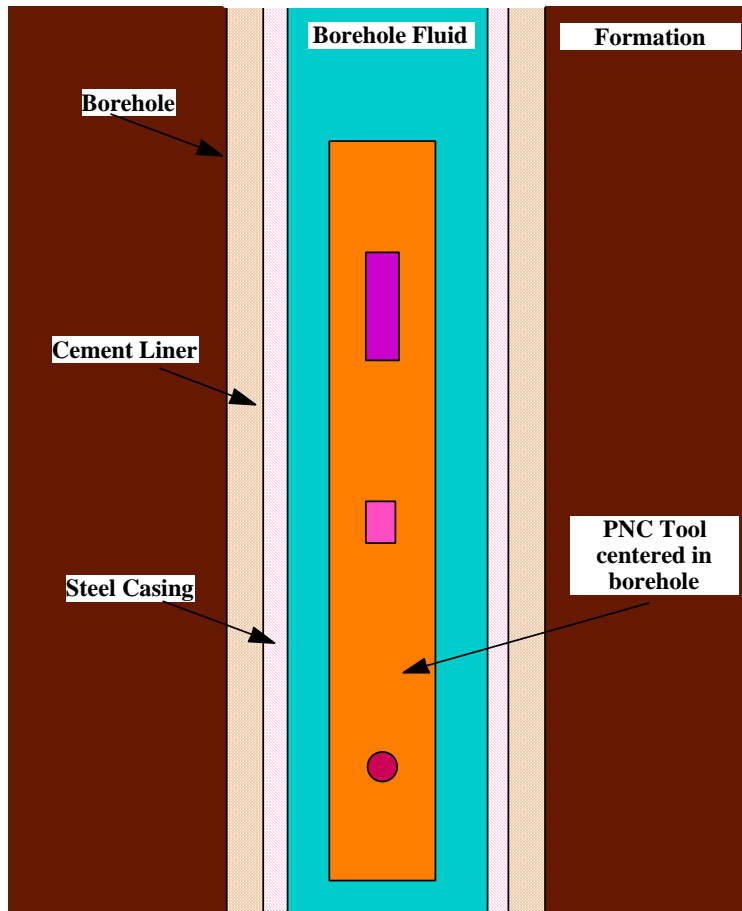
- Medium Energy Gamma Source
- Two scintillation detectors e.g. NaI Crystals
  - ◆ Near (collimated) detector - focussed towards the near bore region
  - ◆ Far detector - looks further into the rock formation
- Gamma-rays are scattered by the electrons in the rock formation
- Energy Deposition or Pulse Height Distribution is scored in the detectors
- Counts in detectors can be related to Formation Density - related to oil bearing properties

# Gamma Density Tool in Inclined Thin Bed Formation



- MCBEND has been used to simulate the response of Gamma Density tools for configurations that cannot be easily reproduced experimentally
  - ◆ e.g. Inclined Thin Beds

# Pulsed Neutron Logging Tool



- High energy pulsed neutron source, two scintillation detectors.
- Neutrons emitted from source collide with nuclei in the rock formation.
- Some collisions emit gamma-rays, which are detected in the detectors of the tool.
- The gamma-ray energies are characteristic of the element in which the collision occurred.
- MCBEND is used to simulate the operation and response of these time dependent tools.

# Summary

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- MCBEND has had many years of successful application in the nuclear industry
  
- Diversification into new markets:
  - ◆ Food Irradiation
  - ◆ Medical
  - ◆ Oil Well Logging
  
- Examples where MCBEND has been used are:
  - ◆ Design of Shielded Facilities
    - Food Irradiation Chamber
    - Hospital Treatment Room
    - Source Calibration Facility
  - ◆ Operational Analysis
    - Food Irradiation Plant
    - Hospital Treatment Planning
    - Irradiator Decommissioning
    - Oil Well Logging

