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Serco Assurance

# Applications of MCBEND

Presentation to

**NPL Workshop on Monte Carlo codes**

by

**Pat Cowan**

**The ANSWERS Software Service**
**Serco Assurance**

# Overview

- 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

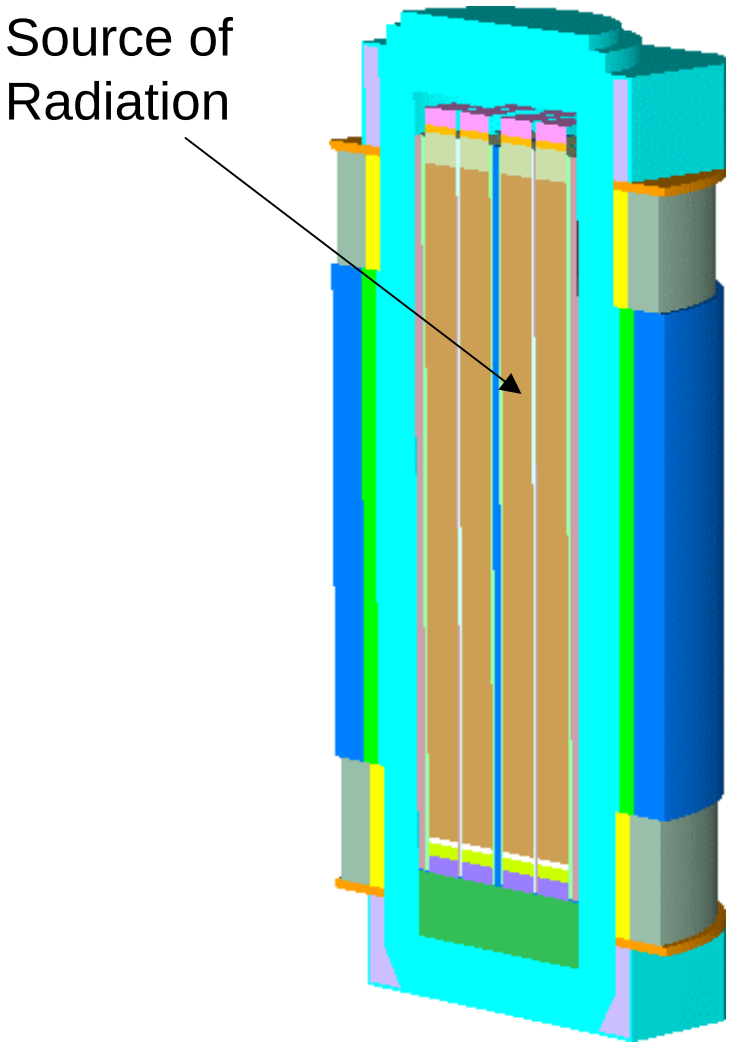
# MCBEND


- 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

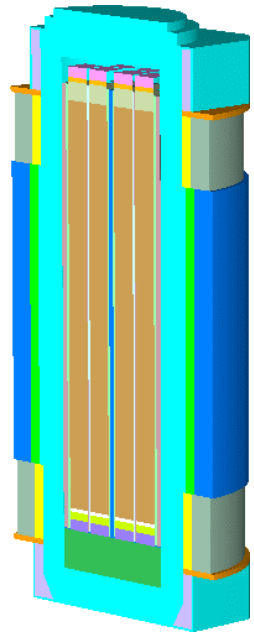
# Typical Nuclear Industry Shielding Problem



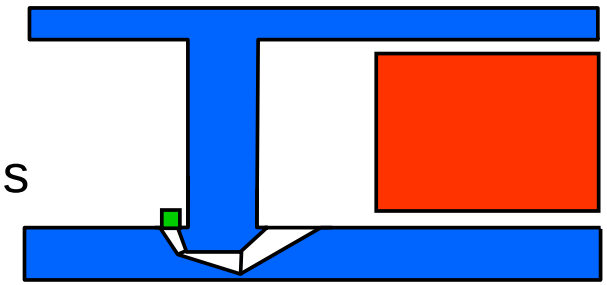

- Design of Radiological Shield
- Determination of external dose-rates

# Problems facing Shielding Assessors

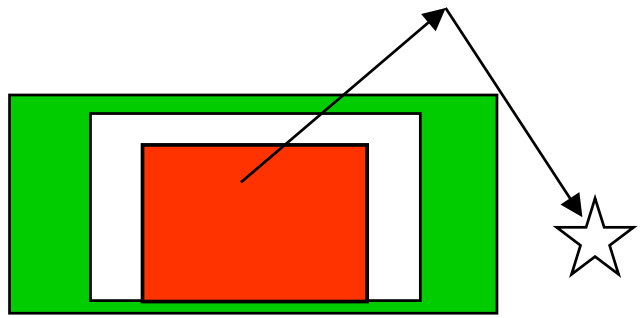
- Dealing with bulk penetration
- Identifying shield weaknesses



- Streaming
  - Ducts, labyrinths

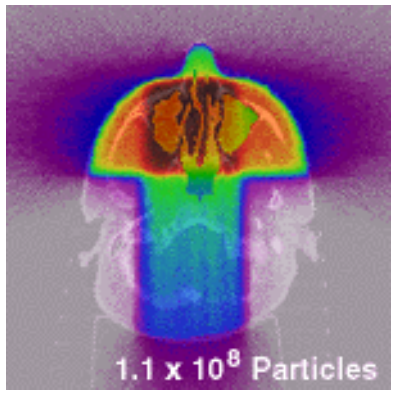


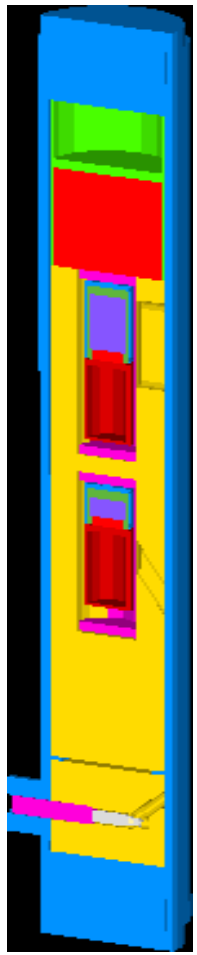
- Skyshine
  - Cask parks
  - Flask transport
  - Waste facilities



# Industrial Applications of MCBEND

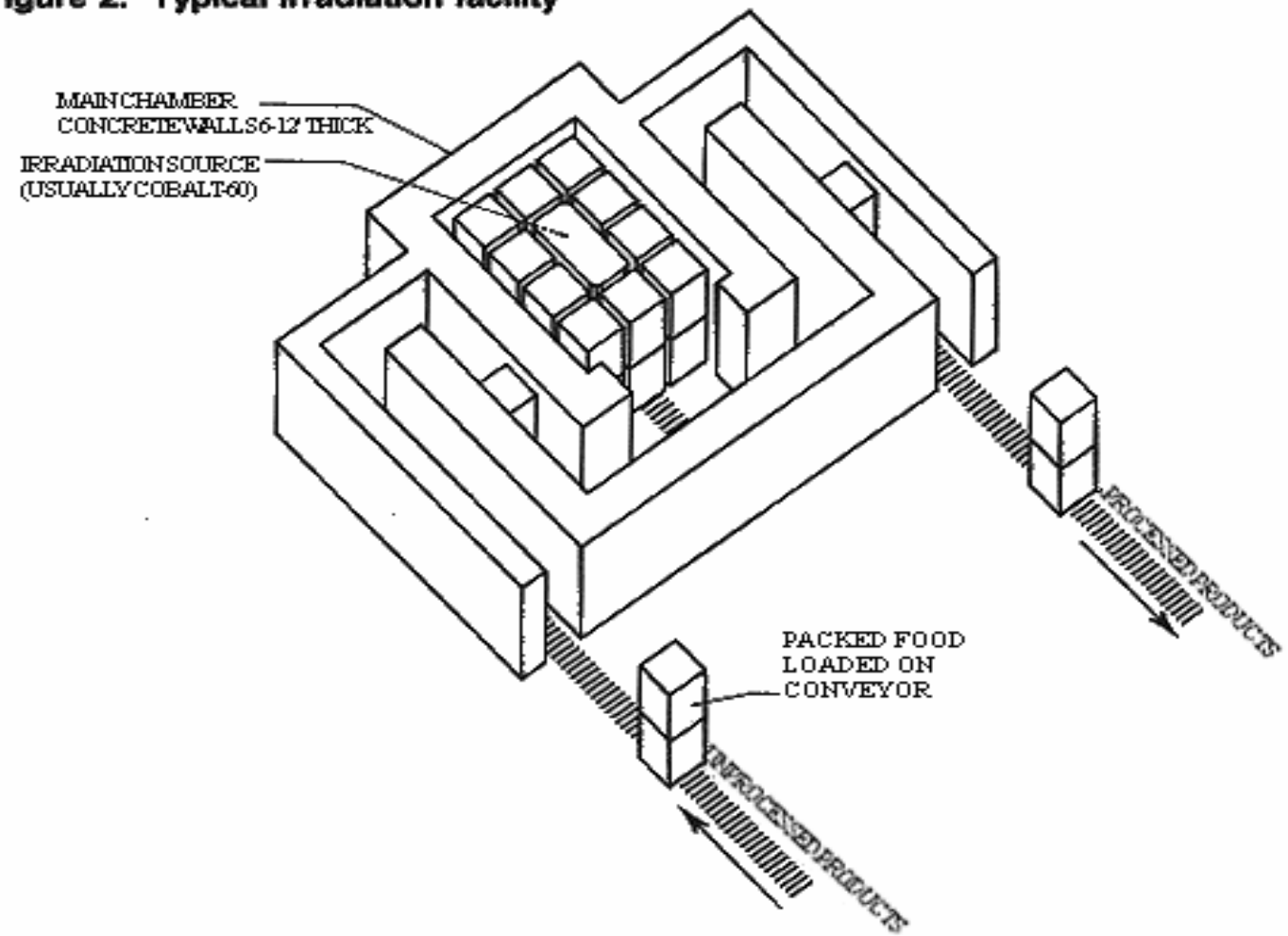
- **Design of Shielded Facilities**
  - Food Irradiation Chamber
  - Hospital Treatment Room
  - Source Calibration Facility
- **Operational Analysis**
  - Dose Uptake in Food
  - BNCT Treatment Planning
  - Irradiator Decommissioning
  - Nuclear Oil Well Logging Tools



# Design of Shielded Facilities

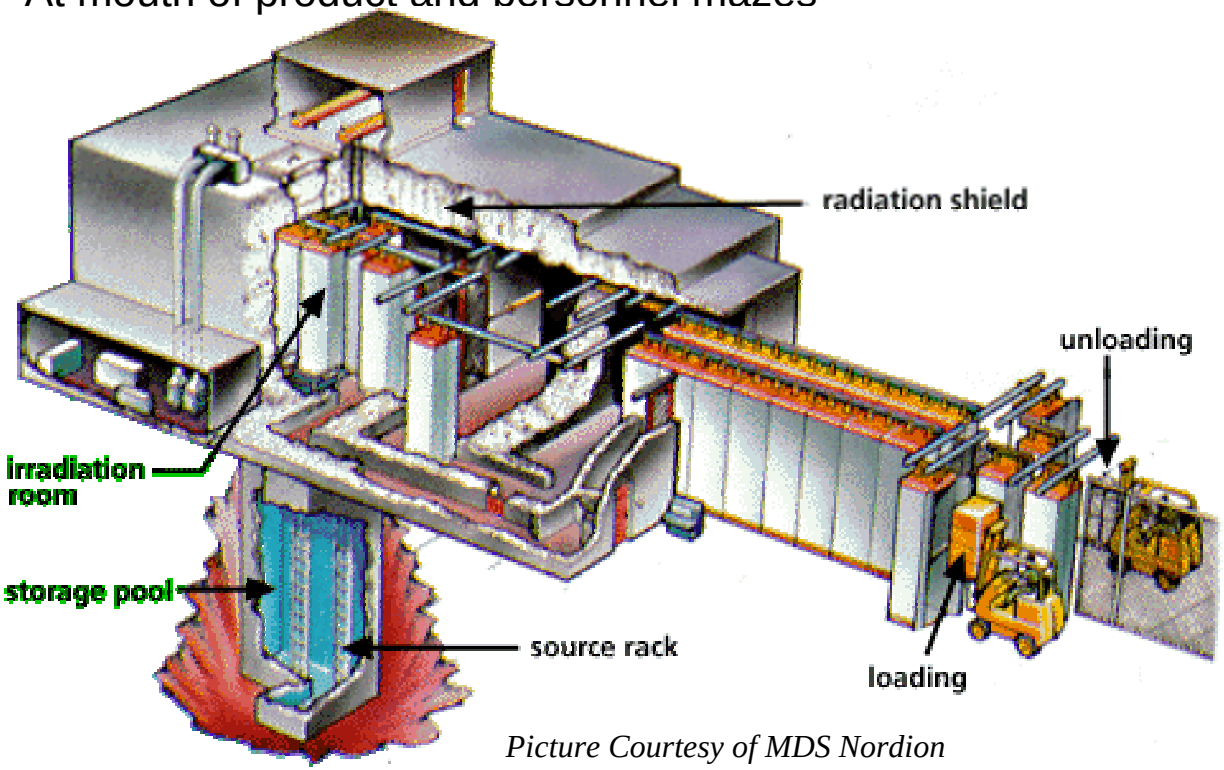
**Figure 2. Typical irradiation facility**




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

# Food Irradiation Chamber

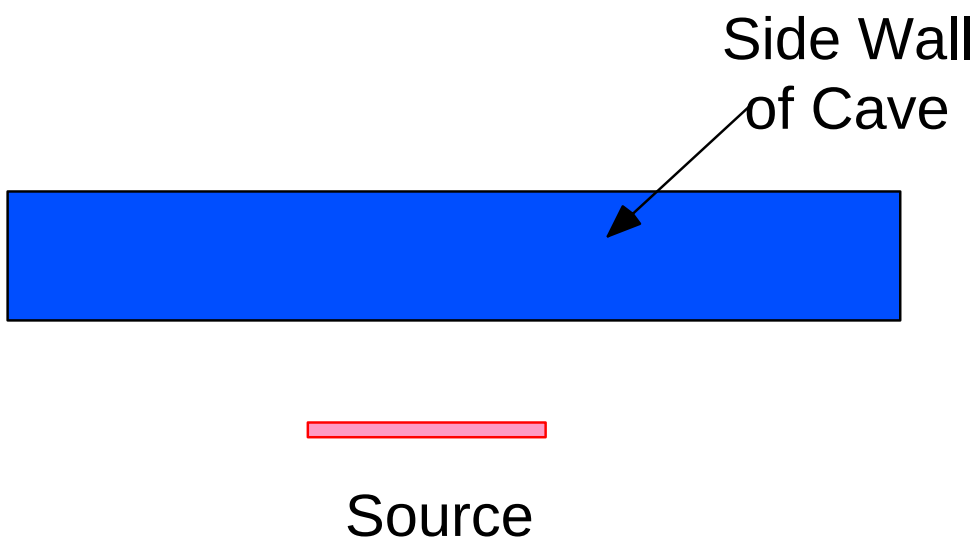
- Food is irradiated by large gamma-ray sources in a heavily shielded cave, to kill off bacteria and preserve it
- MCBEND was used to determine personnel dose-rates outside the chamber:
  - Through the bulk shielding
  - At mouth of product and personnel mazes




*Picture Courtesy of MDS Nordion*

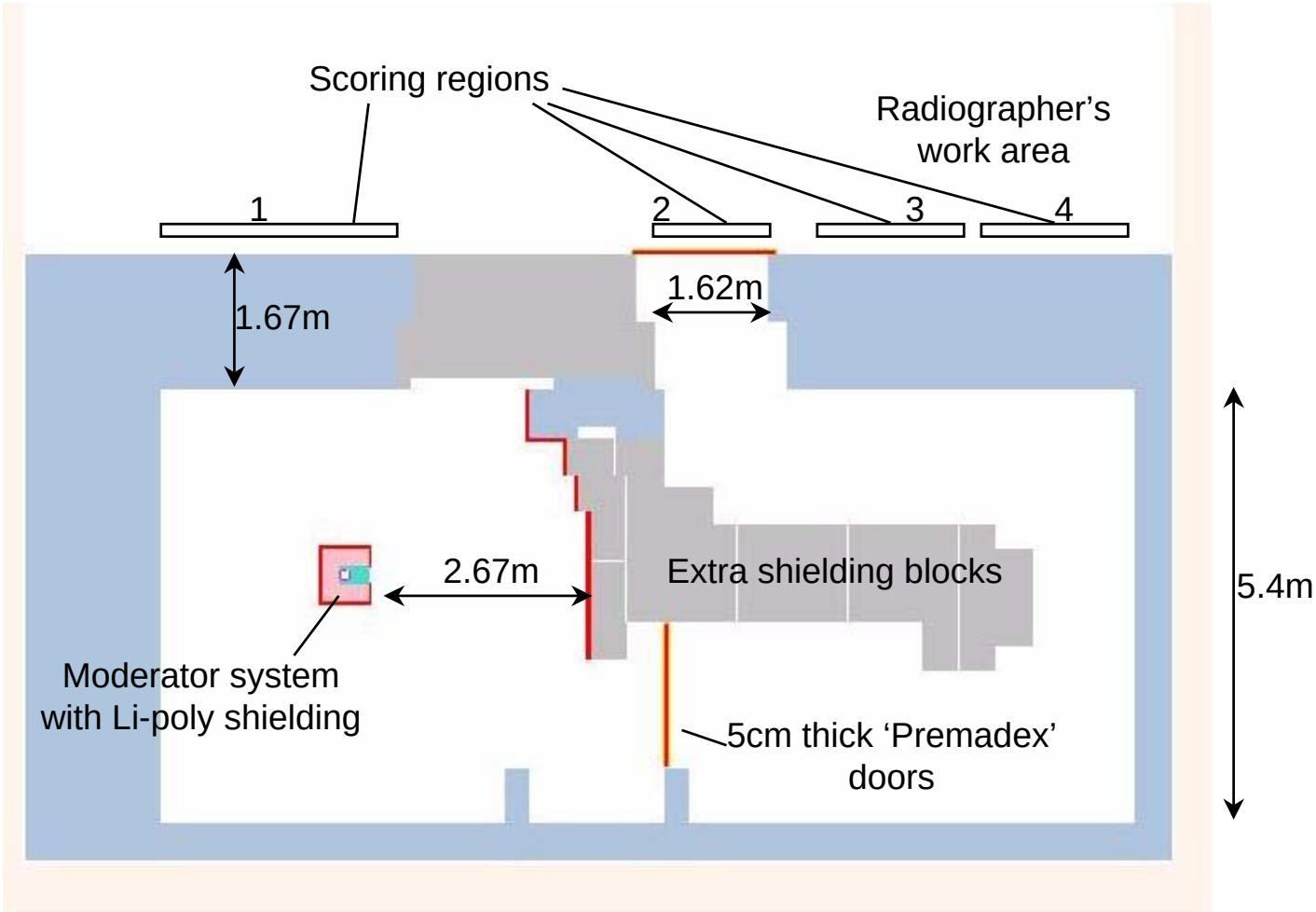
# Food Irradiation Chamber

- 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



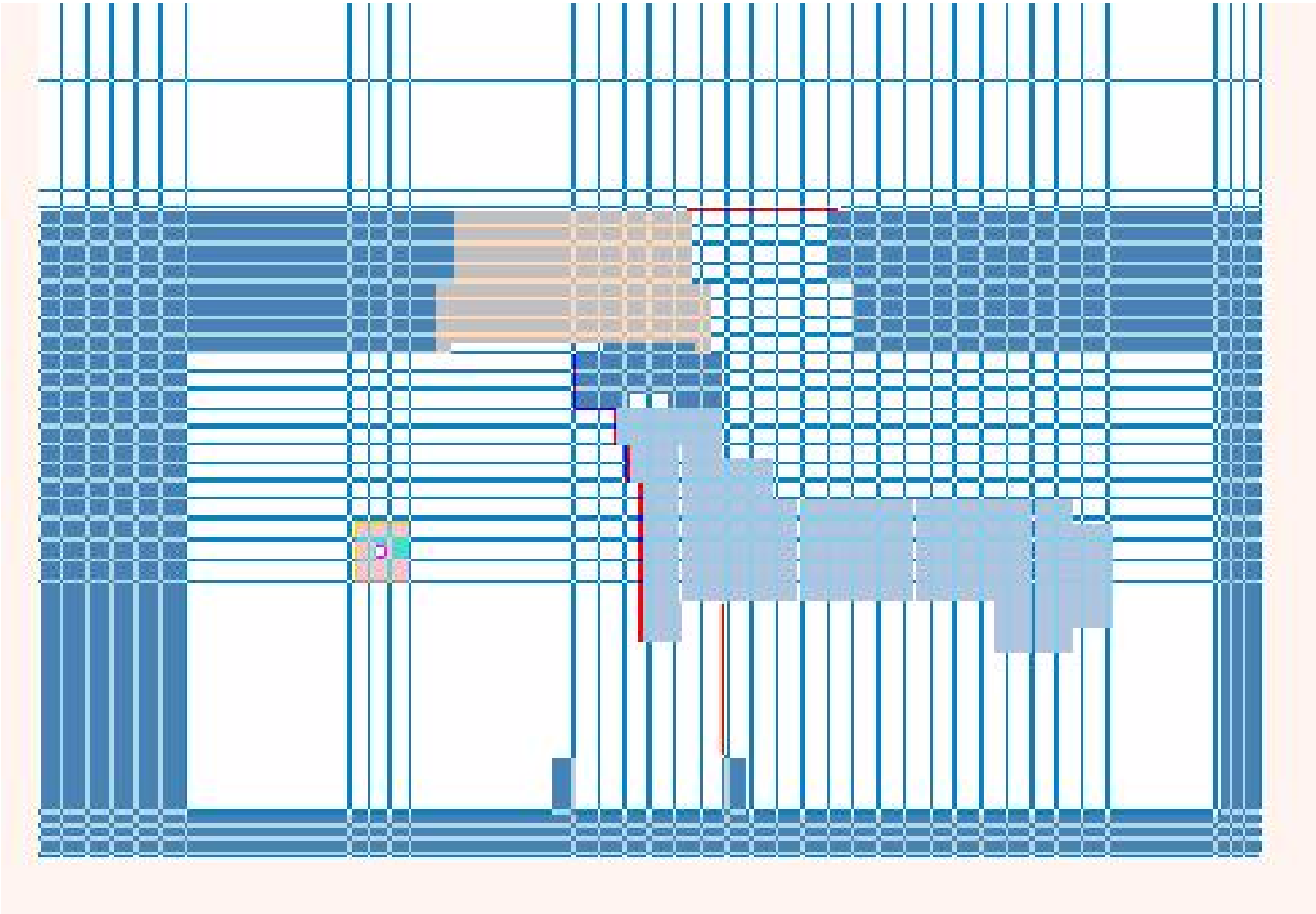
# Hospital Treatment Room

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 (μSv/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**

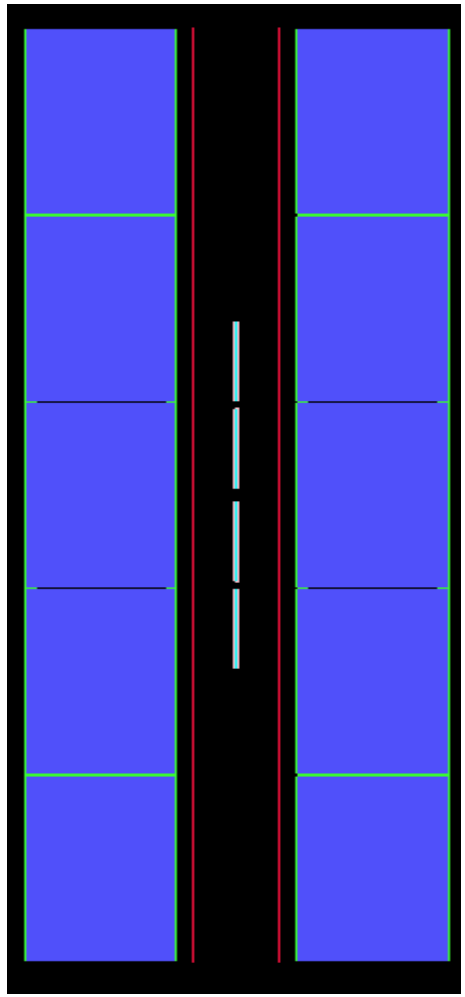
| Scoring region | Dose rate (μSv/hr/mA) | % statistical error |
|---|---|---|
| **2 (doorway)** | 17.7 | 6.9 |
| **3 (radiographer's area)** | 1.02 | 7.1 |

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

| Scoring region | Dose rate (μSv/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.

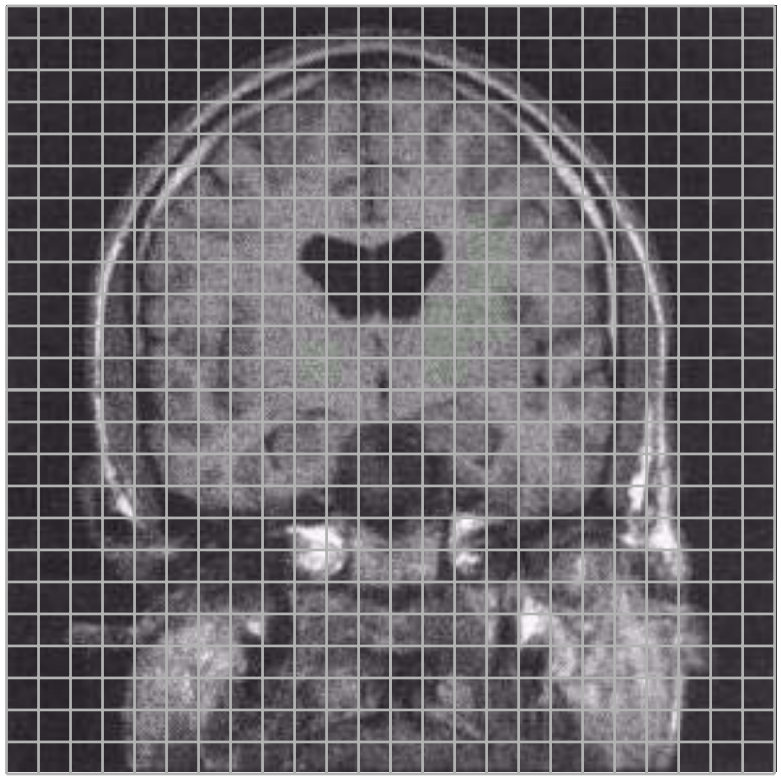


# Operational Analysis – BNCT Treatment Planning

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



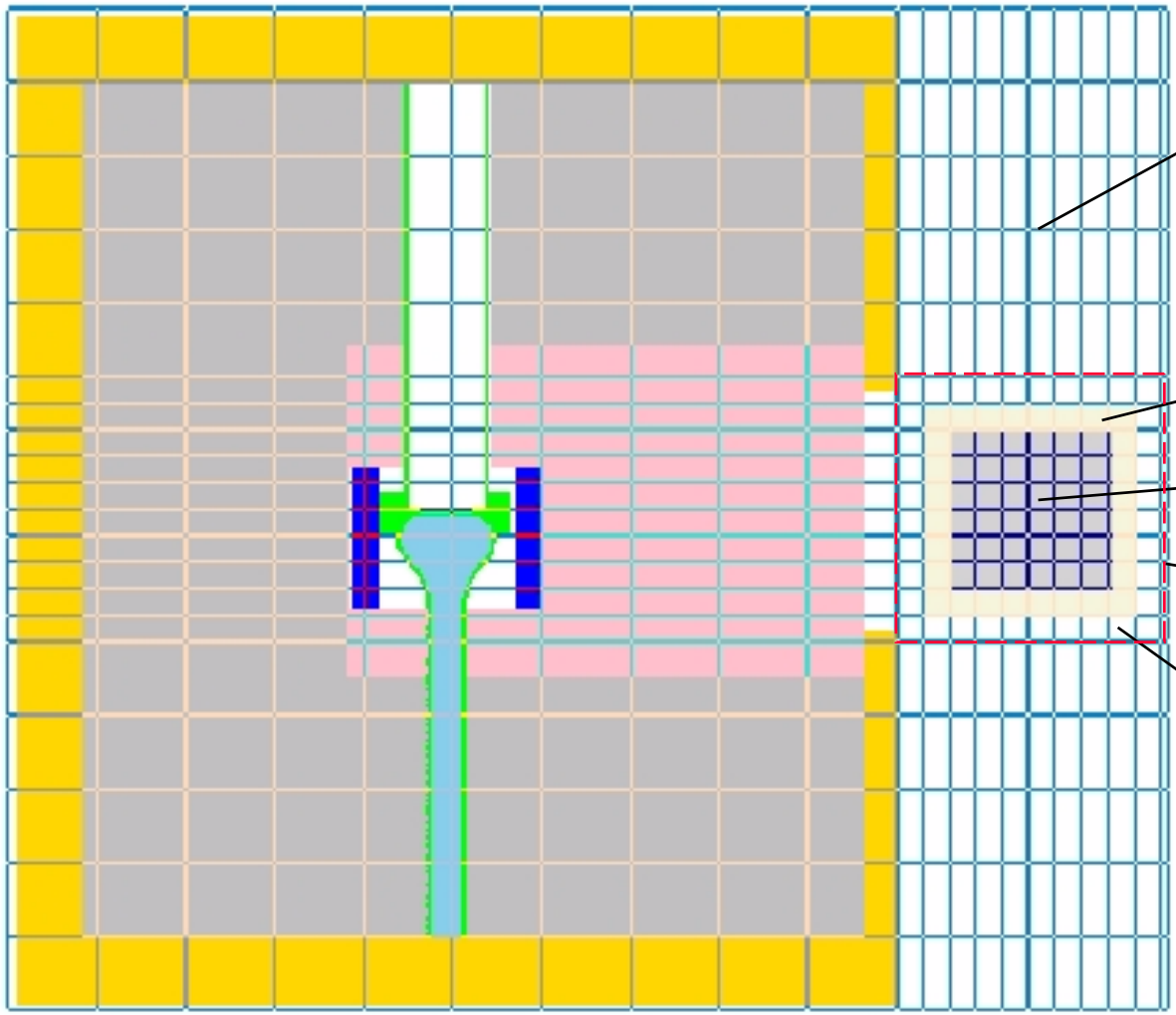
# Operational Analysis – BNCT Treatment Planning

Feasibility Study carried out by Birmingham University

**Phantom model**
10x10x10 array
of 20mm voxels

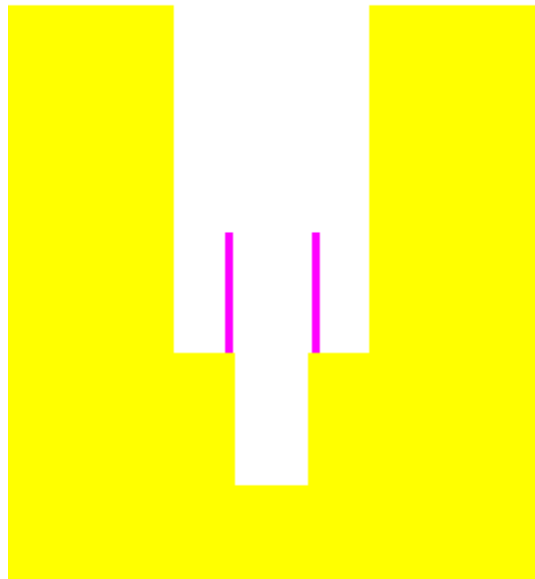
or 20x20x20 array
of 10mm voxels

**Splitting/Scoring Mesh**
10x10x10 array
of 20mm voxels



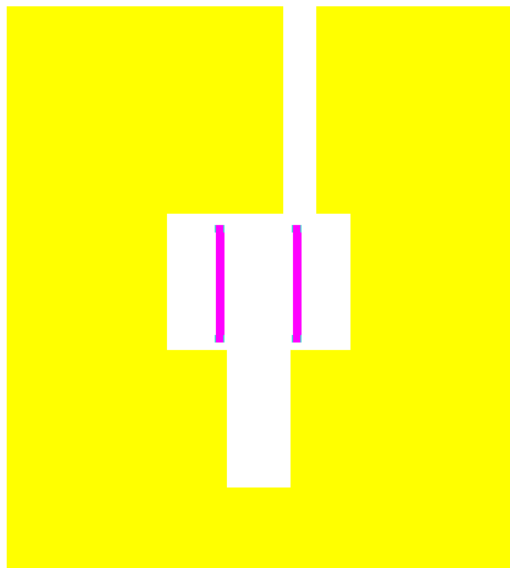
# Operational Analysis – Irradiator Decommissioning

- 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

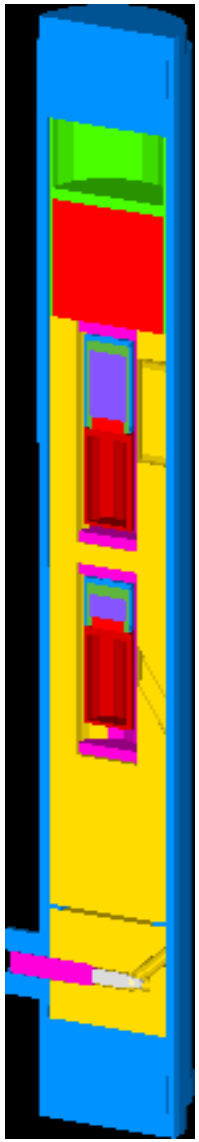
- MCBEND Results
  - Calculations were performed both with and without temporary steel or lead shield plugs located in the top of the irradiator.
  - The optimum design of temporary shield plug was determined, which gave acceptable dose-rates while allowing access to the sources individually for removal.



# Operational Analysis - Oil Well Logging

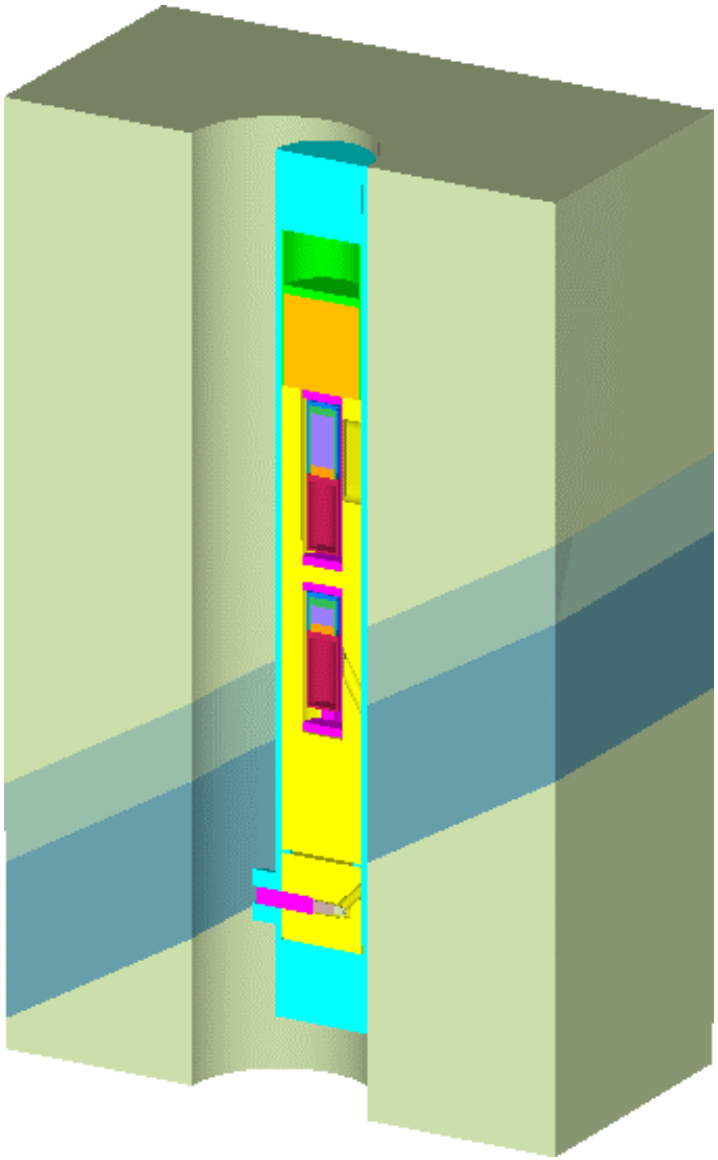
- Oil Well Logging tools are instruments lowered into boreholes, which are used to locate oil.
- As the tool is moved up the borehole, it takes measurements from the surrounding rock formation - which are recorded.
- Even after a well is producing oil, Oil companies may want to log the well to see how 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



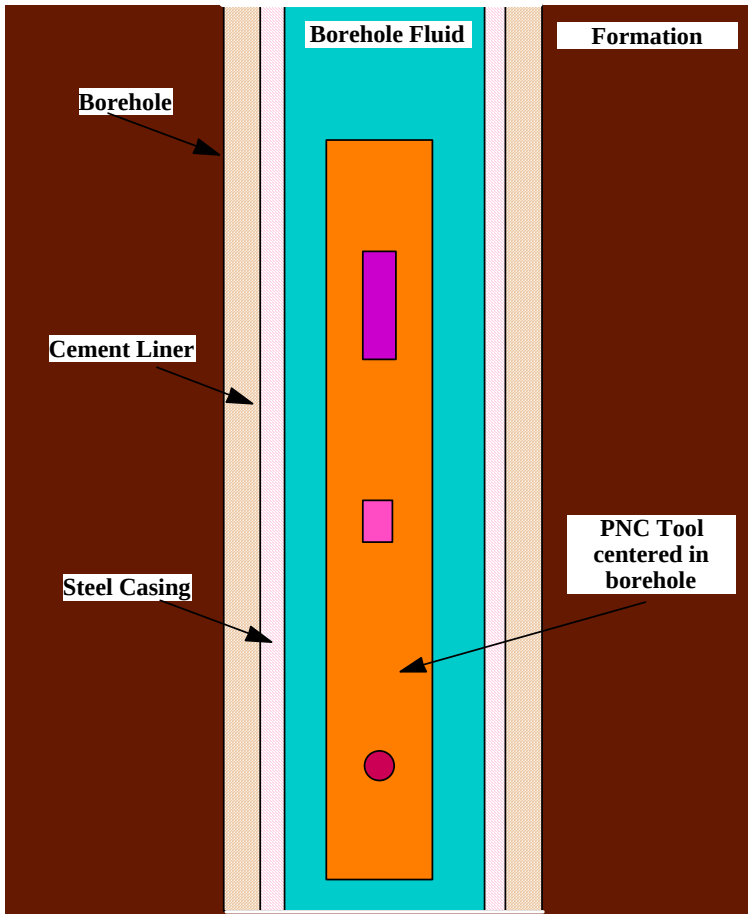
- Medium Energy Gamma Source
- Two scintillation detectors e.g. NaI Crystals
  - Near (collimated) detector - focussed towards the near bore region
  - Far detector - looks further into the rock formation
- Gamma-rays are scattered by the electrons in the rock formation
- Energy Deposition or Pulse Height 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

- 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

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