NCSP TECHNICAL PROGRAM REVIEW, Analytical Methods

Update of the Slide Rule: Recent Outcomes and Perspectives

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

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NCSP NUCLEAR CRITICALITY SAFETY PROGRAM

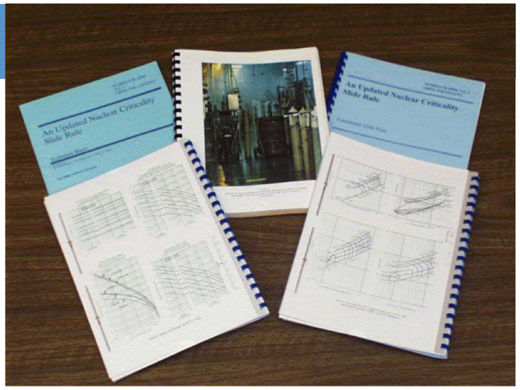
IRSN INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

OAK RIDGE National Laboratory

AWE

March 26, 2019
Amarillo, TX

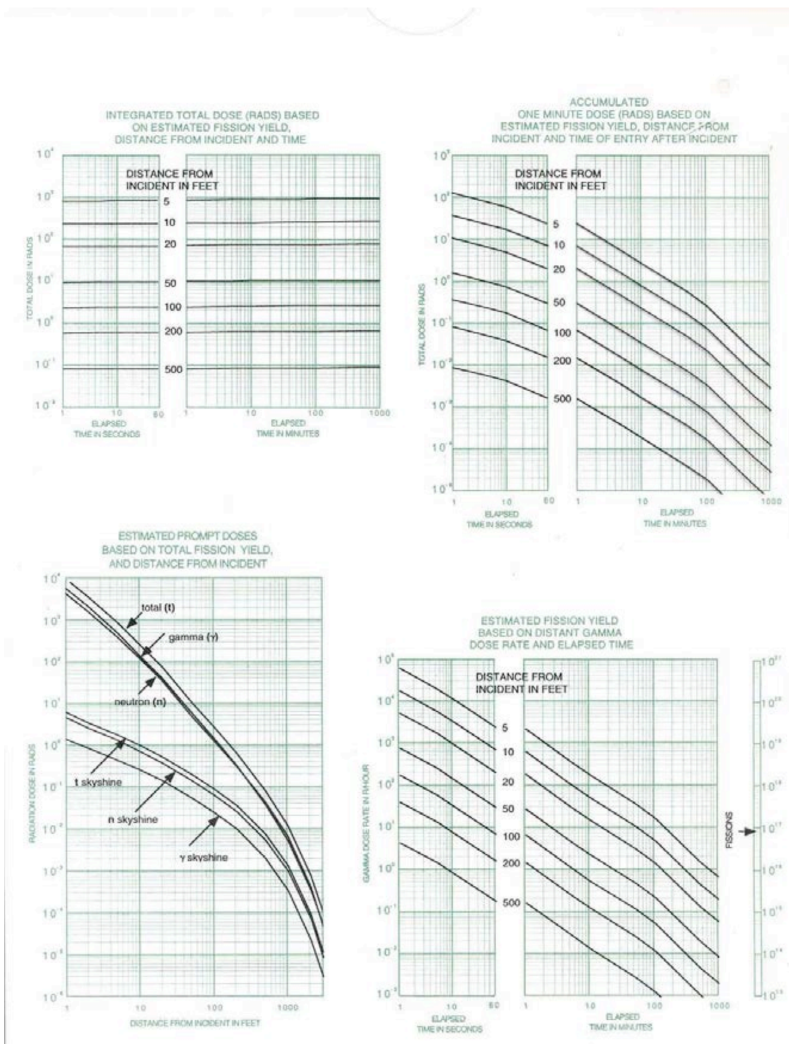
Slide Rule ?



- April 1997, An Updated Nuclear Criticality Slide Rule
  - ORNL/TM-13322/V1 & V2: Technical Basis / Functional Slide Rule

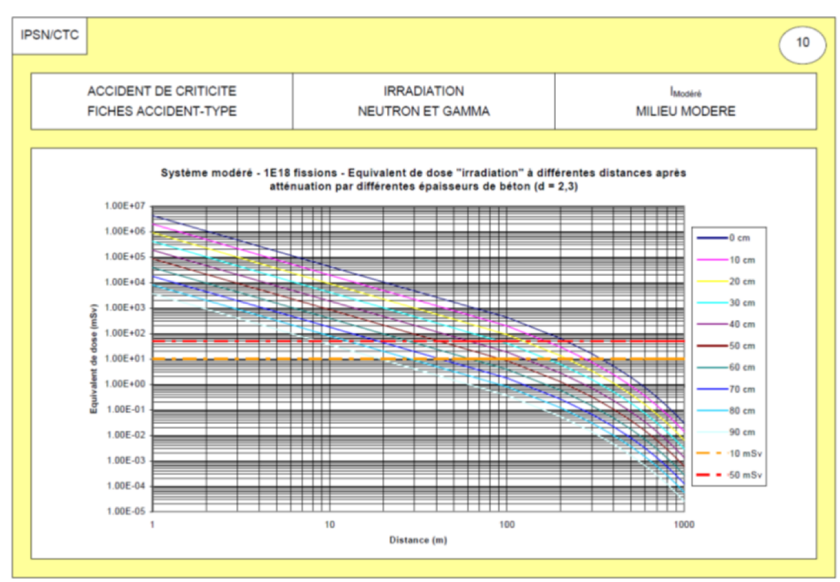
- This document gives order of magnitude estimates of key parameters, useful for emergency response teams and public authorities:
  - The magnitude of the number of fissions based on personnel or field radiation measurements or various critical system parameter inputs,
  - Neutron- and gamma-dose at variable unshielded distances from the accident,
  - The skyshine component of the dose,
  - Time-integrated radiation dose estimates,
  - One-minute decay-gamma radiation dose,
  - and dose-reduction factors for variable thicknesses of steel, concrete and water.

US Slide Rule

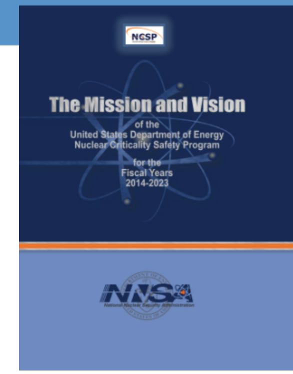


Solution of $U(93.2)O_2(NO_3)_2$ @ $H/^{235}U = 500$

IRSN « Slide Rule »



Long term DOE/NNSA NCSP – IRSN collaboration



- NCSP wants to develop and maintain modern Slide Rule

Accident analysis:		Budget Priority / Technical Priority
Field-deployable emergency response methods on portable, handheld platform	Develop and maintain modern, accident analysis capability (SlideRule)	

- IRSN wants to review and improve its “Slide Rule”

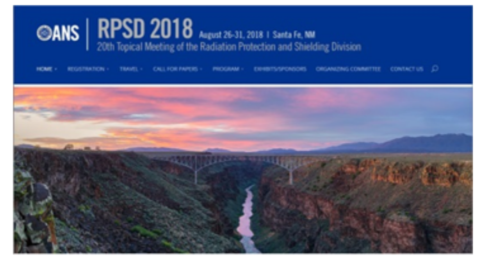
- Proposal of a complete work, divided into several steps:
  - Step 1: Redo with modern radiation transport tools, for the same configurations and assumptions, the calculations performed initially for the 1997 estimation of the doses

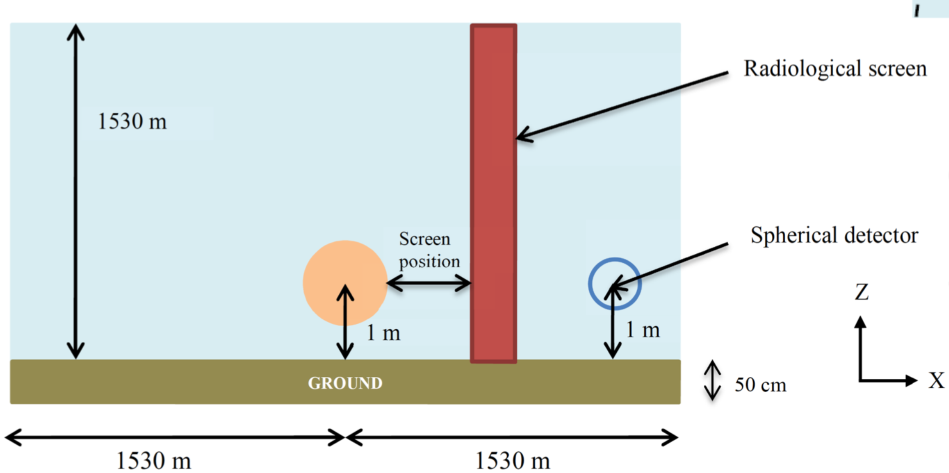
  - Step 2: Perform additional configurations/calculations
    - New configurations (new geometry of the source, new fissile media <u>including plutonium systems</u>, etc.)
    - New flux-to-dose conversion factors

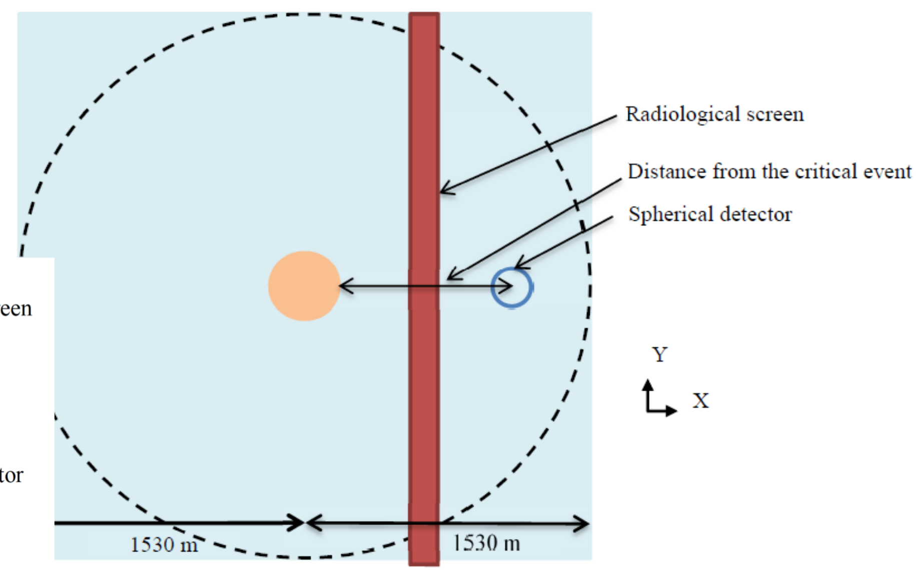
2017 NCSD Topical Meeting
September 10-15, 2017 | Carlsbad, NM | Pecos River Village Conference Center

FY2018 - Continuation of Step 2 – Studies with common shielding materials

- Various thicknesses of concrete (20 and 40 cm), lead, stainless steel 304, and water (1, 5, 10 and 20 cm)
- Sources: HEU metal (C4) and LEU uranyl fluoride solution (C1)
- Shield always positioned halfway between the source and detector
- Also evaluate the effect of humidity and ground composition on dose







Computational Tools and Data

- All cross sections continuous energy and based on ENDF/B-VII.1
- Flux-to-dose conversion factors taken from ANSI-HPS 13.3-2013 (Dosimetry for Criticality Accidents)
  - Different from previous slide rules that used Henderson dose factors
- MCNP 6.1
  - Two-step method
    - 1) Kcode simulation to generate energy and spatial distribution of neutrons
    - 2) SDEF simulation of neutron and photon doses with neutron multiplication turn off
  - Used ADVANTG to provide weight windows and source biasing for SDEF simulation

Computational Tools and Data (cont.)

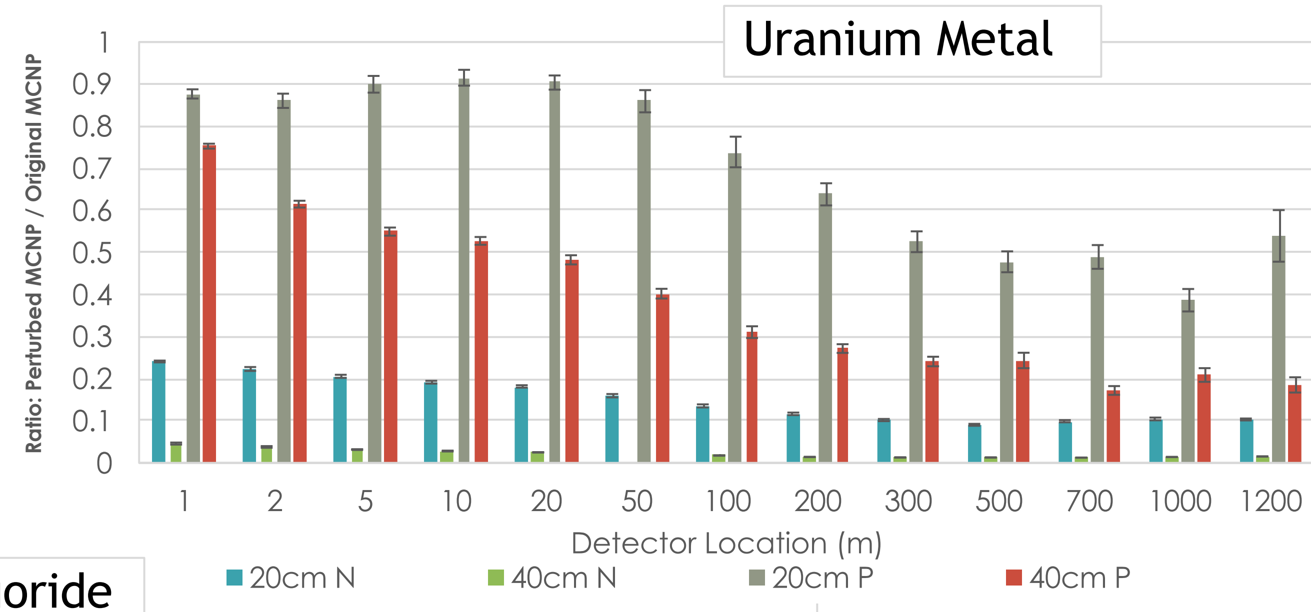
SCALE 6.2.2

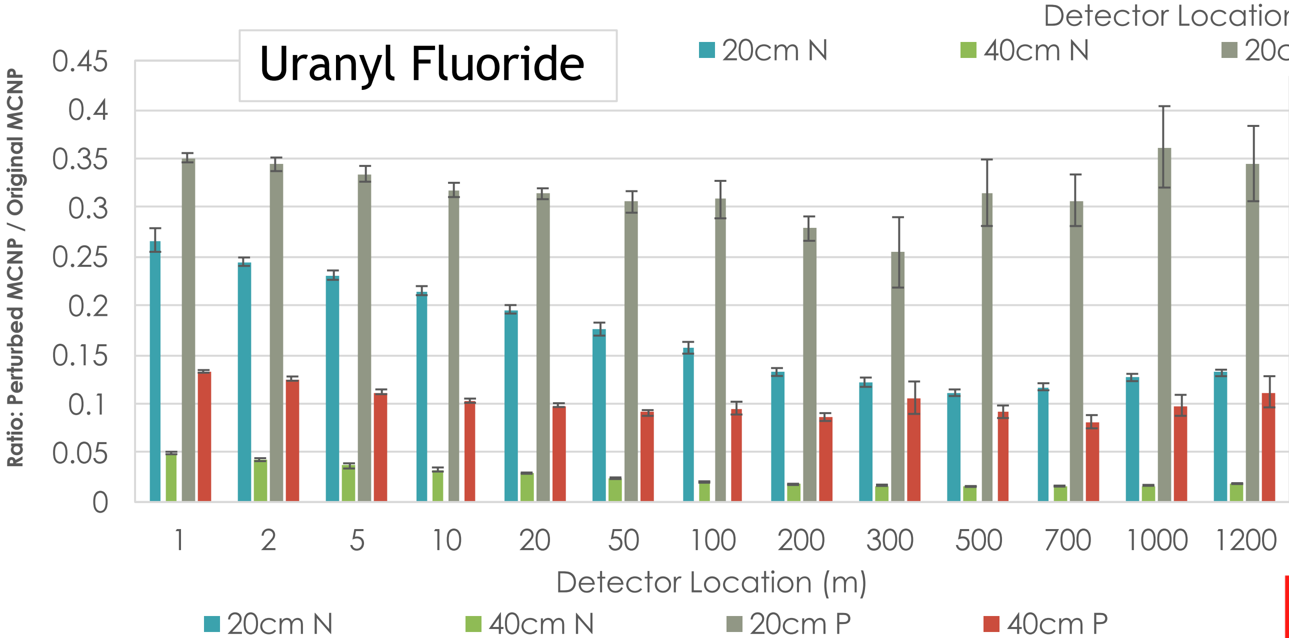
- Also used two-step method
  - 1) KENO-VI simulation to generate energy and spatial distribution of neutrons
  - 2) MAVRIC/Monaco simulation of neutron and photon doses with neutron multiplication turn off
- Weight windows and source biasing provided by the MAVRIC sequence

COG 11.2

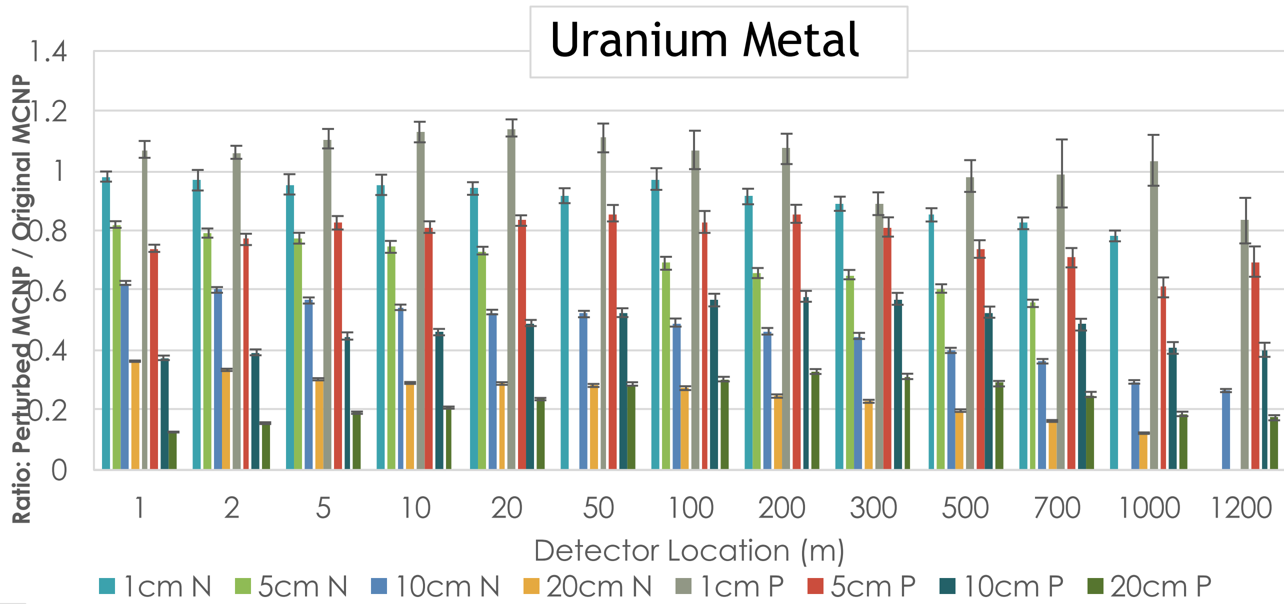
- One-step method, i.e., eigenvalue simulation with neutron and photon dose tallies

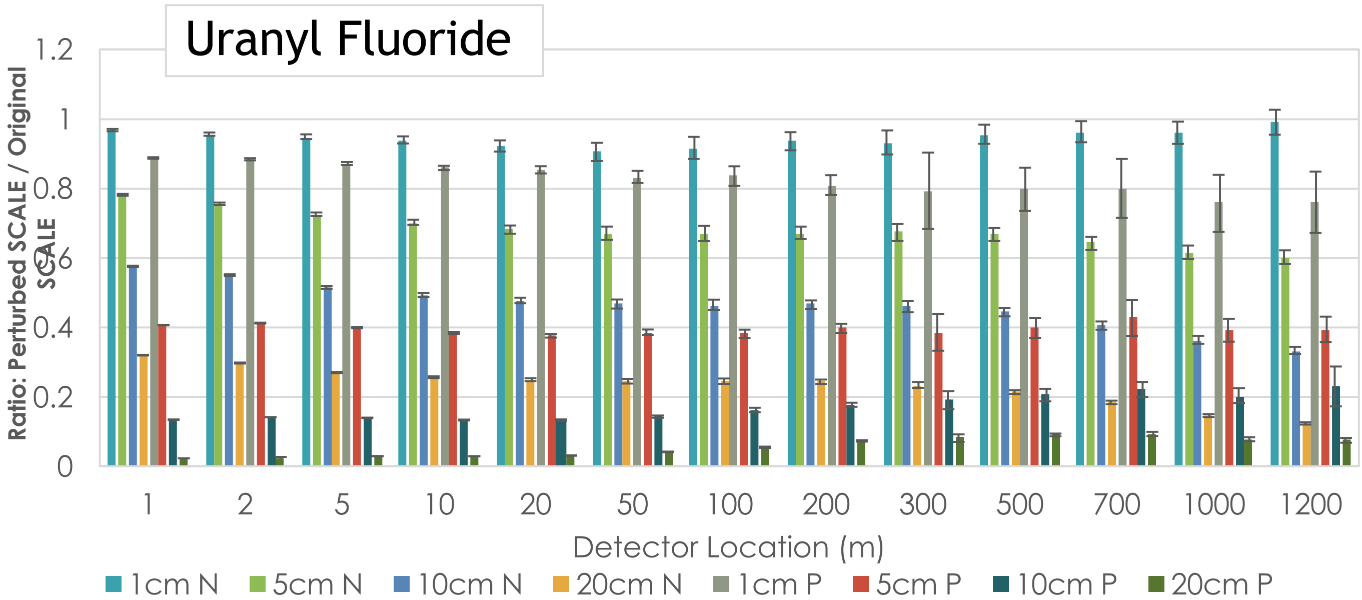
Shielding Ratio: Concrete / No Concrete



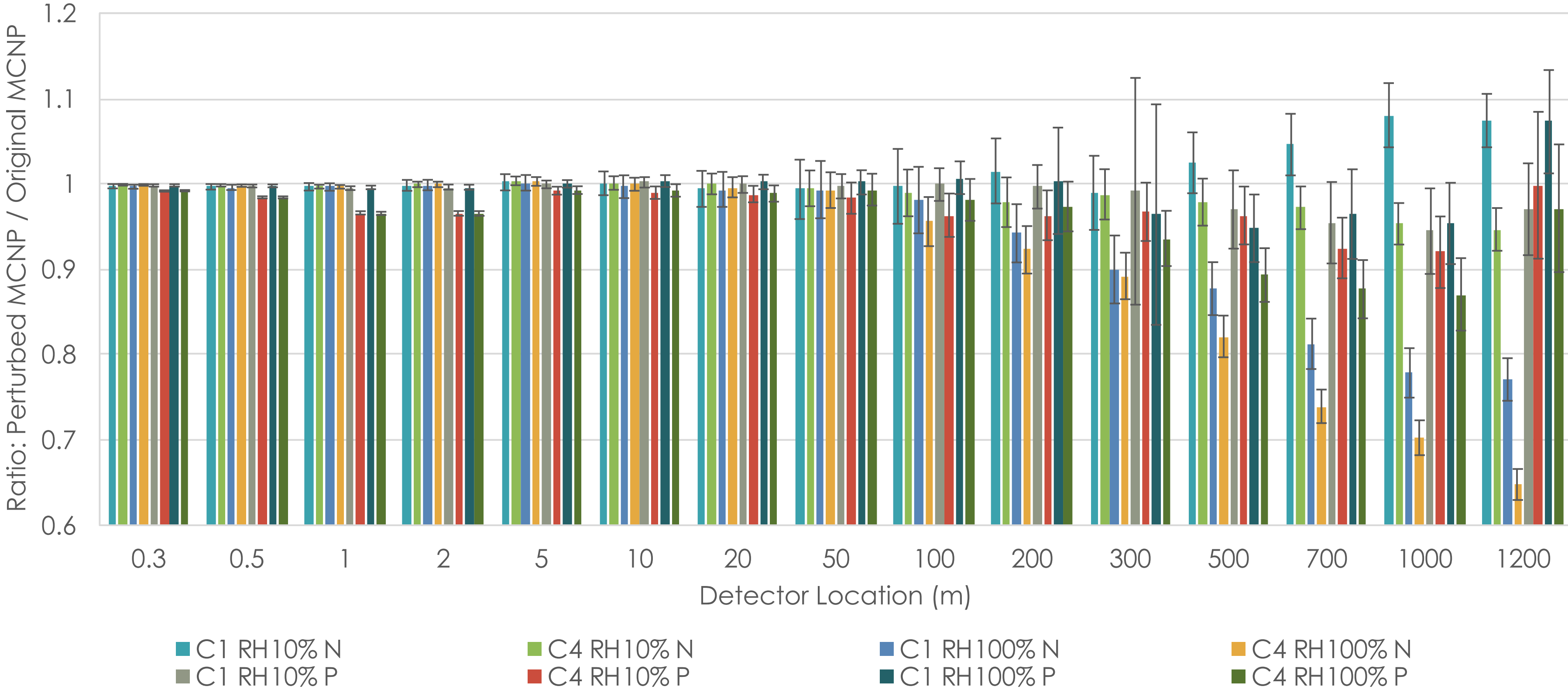


Shielding Ratio: Stainless Steel 304 / No Stainless Steel 304

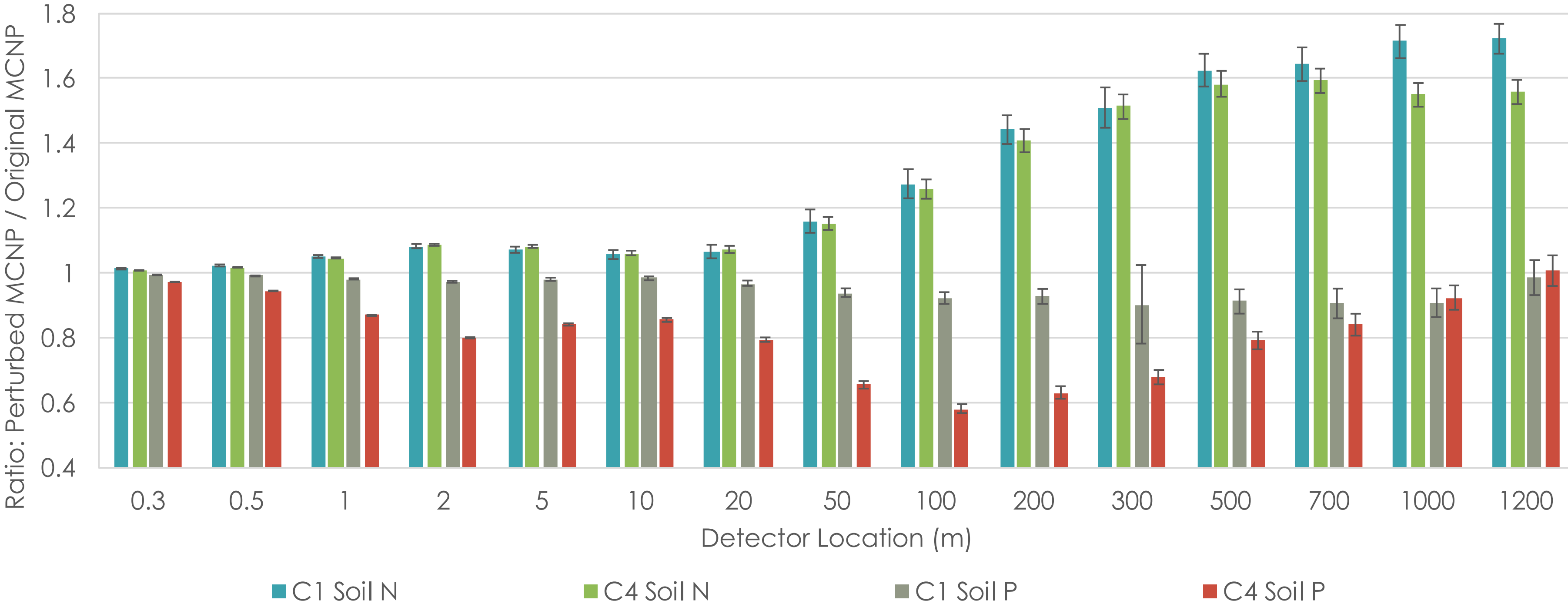




Air Composition Ratio: Humid Air / Dry Air



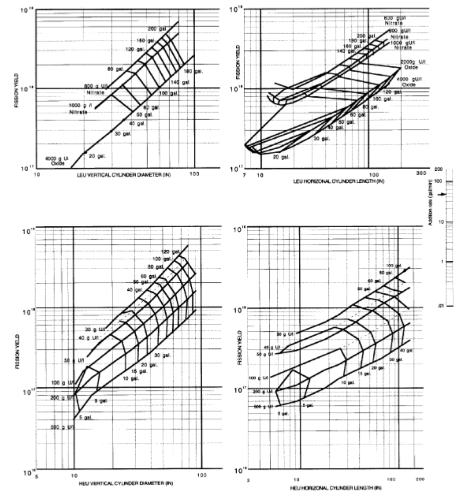
Ground Composition Ratio: Dry Soil / Concrete



Results summary

- **Shielding**
  - Typical attenuation results (i.e., thicker shield more attenuation, high Z shields gammas, low Z shields neutrons)
  - For photons, dose builds up for some distances and shielding
  - Dose attenuation factor might be dependent of the distance…
- **Humid air**
  - Small impact on photons, decrease neutron dose >100 m from source ~35% max
- **Dry soil for ground**
  - Small decrease uranyl fluoride photon dose, decrease U metal photon dose ~40% at 100 m but no difference at 1.2 km
  - Increase neutron dose as much as 70%

Perspectives



- **Step 2:**
  - Delayed Gamma dose for Plutonium systems
  - Skyshine dose

- **Step 3:**
  - Review and improve the section regarding the estimation of the number of fissions

- **Opportunity to create “computer benchmarks”:**
  - Test and validate the various variance reduction methods
  - Establish best practices for this kind of problems (e.g. fission source calculation)

  → Kenneth Burn (ENEA), “Employment of the Single Eigenvalue Monte Carlo Technique to some Criticality Safety Problems; Comparison with a Standard, Mixed Deterministic – Monte Carlo Approach,” ICNC 2019

NCSP website: Analytical Methods

https://ncsp.llnl.gov/am_criticality_sliderule.php

About the Nuclear Criticality Slide Rule Project

AWE (UK), IRSN (France), LLNL (USA) and ORNL (USA) began a long-term collaboration effort in 2015 to update the Nuclear Criticality Slide Rule for emergency response to a nuclear criticality accident to modernize and expand the technical content of the previous (1998 version) last updated by ORNL.

The detailed plans and accomplishments of the project are provided in the task specifications and summary papers provided below. For additional information on this project, please contact the project coordinator, Matthieu Duluc (IRSN) at matthieu.duluc@irsn.fr.

Phase	Document Type	Title	Date
3	Task Specification	Update of the Nuclear Criticality Slide Rule Calculations – Sensitivity Studies	2017 Sep 12
2	Summary Paper	Introduction of Plutonium Systems to the Nuclear Criticality Slide Rule ANS NCSD Topical, Carlsbad, NM, USA	2017 Sep 14
	Task Specification	Update of the Nuclear Criticality Slide Rule Calculations – Plutonium Configurations	2017 Mar 24
1	Summary Paper	Update of the Nuclear Criticality Slide Rule for the Emergency Response to a Nuclear Criticality Accident, EPJ Web of Conferences 153, 05015 (2017) ICRS2016 – RPSD2013, Paris, France	2016 Oct 5
	Task Specification	Update of the Nuclear Criticality Slide Rule Calculations – Initial Configurations	2015 Dec 10

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Thank you for your attention

Special thank for Thomas MILLER and Marc TROISNE for their major contribution to this work

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