IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Joint IAEA–Consultative Committee for Ionizing Radiation Workshop on Neutron Beams at High Energy: Applications and Metrology

IAEA Headquarters
Vienna, Austria

7 - 8 July 2025

Motivation for this workshop:

- Metrology community is still searching for a reference facility for high energy neutron metrology

- Aim: Better connection/bridge between different communities:
  - Metrology
  - Nuclear data experts
  - Facilities
  - Stakeholders (i.e. users dealing with high energy neutrons)

Day 1: Health and Radiation Protection; Science and Technology

- Aviation, Space and Radiobiology
- Accelerator Facilities 1
- Accelerator Facilities 2
- Materials and Instrumentation
- Nuclear data

Day 2: Neutron metrology, high energy neutron facilities and reference standards

- Neutron metrology
- High energy neutron facilities (present and planned)
- Reference standards (instrumentation and cross sections)

117 registered participants

44 submitted abstracts

Day 1: Health and Radiation Protection; Science and Technology

- 18 talks selected from the abstracts
- 13 posters

Day 2: Neutron metrology, high energy neutron facilities and reference standards

- 6 talks
- More general/overview talks
- More time for discussions

Scientific commitee:

- Andy Buffler (University of Cape Town)
- Marco Caresana (Politecnico di Milano)
- Vincent Gressier (BIPM)
- Fabio Pozzi (CERN)
- Neil Roberts (NPL)
- Andreas Zimbal (PTB)
- Ralf Nolte (PTB)
- Nelson Magalotti (IRSN)
- Tetsuro Matsumoto (NMIJ)
- Arjan Koning (IAEA)
- Roberto Capote Noy (IAEA)
- Valentina Semkova (IAEA)

… and a very special thanks to Lidija Vrapcenjak (IAEA)

CCRI

Activities of the Section CCRI(III) - Neutron Metrology

July 2025

Andreas Zimbal, Chair Section (III) – Neutron Metrology

CONSULTATIVE COMMITTEE
FOR IONIZING RADIATION

A few words about metrology: The Metre Convention

Established in 1875 when 17 States signed the Metre Convention, now with 64 Member States and 36 associates.

CGPM – Conférence Générale des Poids et Mesures

Decision-making body, meets every 4 years

Decides on matters related to SI and Metre Convention

CIPM – Comité International des Poids et Mesures

18 members, elected by the CGPM

Coordinates actions to promote world-wide uniformity of measurement

Advised by Consultative Committees

BIPM – Bureau International des Poids and Mesures

70 people

International coordination and liaison

Technical coordination – laboratories

Capacity building

10 Consultative Committees (CCs)

CCAUV – Acoustics, US & Vibration

CCEM – Electricity & Magnetism

CCL – Length

CCM – Mass and related

CCPR – Photometry & Radiometry

CCQM – Amount of substance

CCRI – Ionizing Radiation

CCT – Thermometry

CCTF – Time & Frequency

CCU - Units

Structure of international metrology

National Metrology Institutes (NMIs)

- One per Member or Associate State
- Appointed by government
- Holds national standards (primary or secondary)

Designated Institutes (DIs)

- Holds national standards for a particular field
- One per field of measurement
- Appointed by NMI

Secondary Standard Dosimetry Laboratories

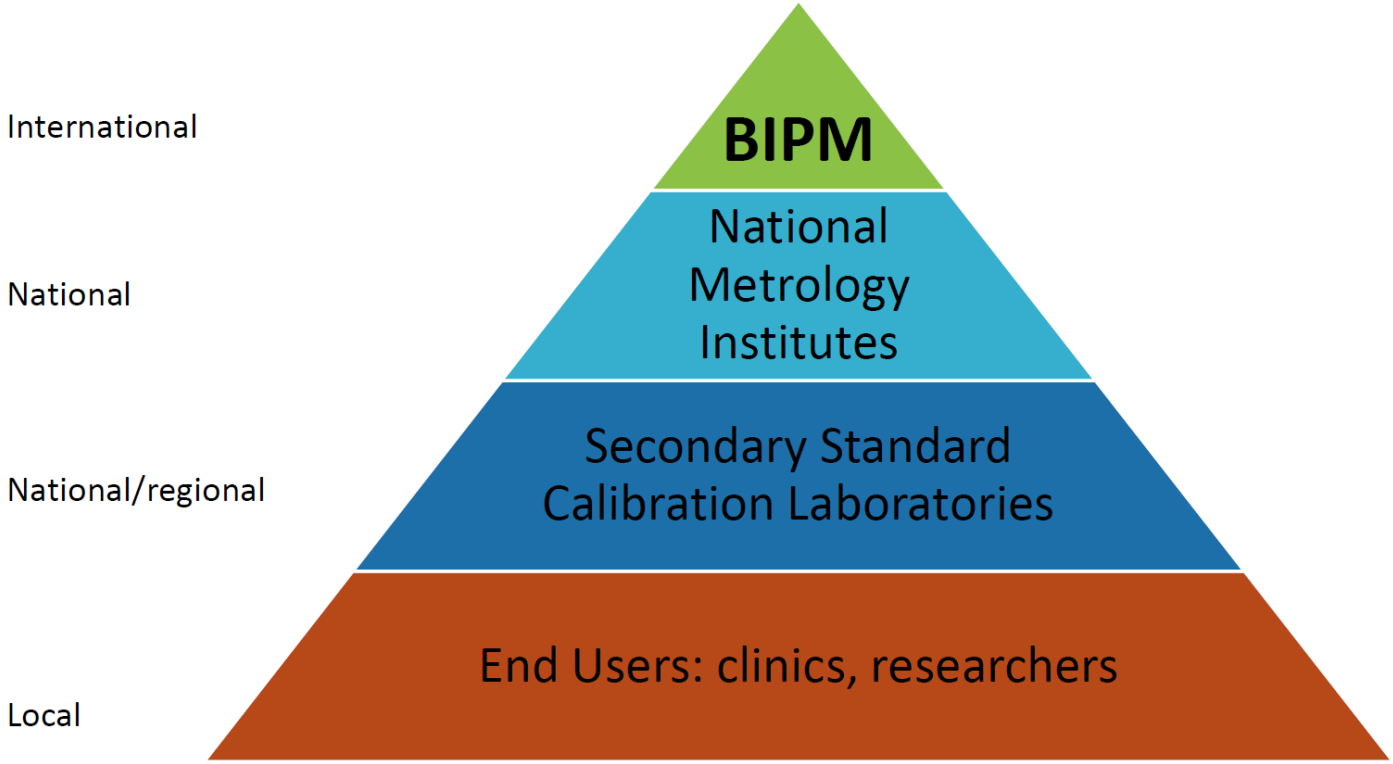
- Members of a separate network – the IAEA/WHO SSDL network
- May also be a DI or NMI

Regional Metrology Organizations (RMOs)

The CIPM Mutual Recognition Arrangement (MRA)

- Established in 1999 to provide the technical basis for worldwide acceptance of national measurement standards, calibrations, and certificates from signatories
- 250 signatories, including 97 NMIs, 149 DIs, and 4 International Organizations
- From practical standpoint, enables an NMI's standards to be recognized and applied internationally, even in countries without an NMI
- Each laboratory's Quality Management System is key to demonstrating how traceability is established and maintained

Metrology hierarchy



Consultative Committee for Ionizing Radiation (CCRI)

Founded in 1958

President: JT Janssen (NPL)

Executive Secretary: V. Gressier (BIPM)

- **13 Members:** BEV, LNE, CMI, Rosstandart, METAS, KRISS, NIM, NIST, NMIJ, NMISA, NPL, NRC, PTB
- **10 Observers:** GUM, CEM, ENEA, BFKH, INMETRO, INM, NMIA, NSC IM, SMU, VSL
- **5 Liaison organisations:** CTBTO, IAEA, ICRU, ISO TC85/SC2, JRC-GEEL

Section I
X- & γ-rays
Charged Particles
Chair: Malcolm McEwen (NRC)

33 NMI/DIs

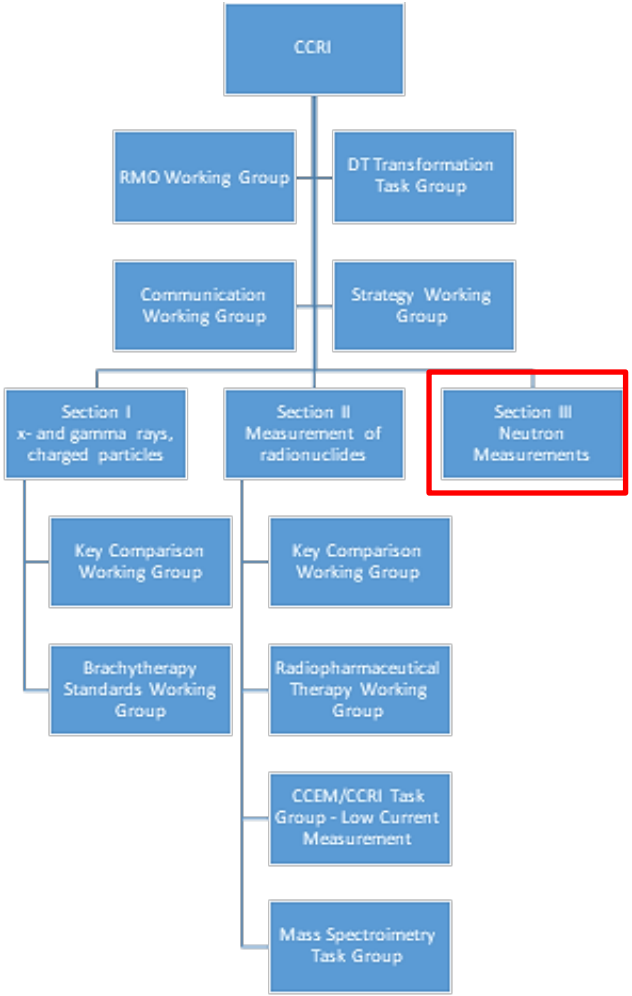
Section II
Measurement of
Radionuclides
Chair: Lisa Karam (NIST)

23 NMI/DIs

Section III
Neutron
Measurements
Chair: Andreas Zimbal (PTB)

19 NMI/DIs

Total of 34 states and economies and 7 liaison organisations across all RMOs



Structure of CCRI

CCRI(III): Neutron Measurements

Chair: **Andreas Zimbal (PTB)**, vice chair: **Neil Roberts (NPL)**

Meet every 2 years (most at BIPM, Paris): 2023, 2025, …

Main work:

- **Discuss and organize key comparisons**

CCRI Section 3: Neutron measurements

Chair:

Dr Andreas Zimbal

Physikalisch-Technische Bundesanstalt, Germany

Vice-Chair:

Mr Neil Roberts

National Physical Laboratory, United Kingdom

CCRI(III) Members and Liaison Organizations

- Members (20), 9 of them from EURAMET:

  BARC (Mumbai), CIEMAT (Madrid), CIAE (Beijing), CMI (Brno), VNIIM (St Petersburg), ENEA-INMRI (Rome), iThemba LABS (Somerset West), KRISS (Daejeon), LNE (Paris), NIM (Beijing), IFIN-HH (Bucharest – Magurele), NIST (Gaithersburg), LNMRI/IRD (Rio de Janeiro), NMIJ/AIST (Tsukuba), NMISA (Pretoria), NPL (Teddington), NRC (Ottawa), SCK.CEN/LNK (Mol), PTB (Braunschweig), SMU (Bratislava)

- Liaisons (4):

  JRC-Geel (Geel), IAEA (Vienna), ICRU, ITER (St. Paul-lez-Durance)

Main activity of CCRI(III): Comparisons

Key comparions:

For emission rate:

- ^{241}AmBe
- ^{252}Cf

For fluence:

- Monoenergetic neutrons
- Thermal neutrons

Supplementary comparions:

For dose quantities:

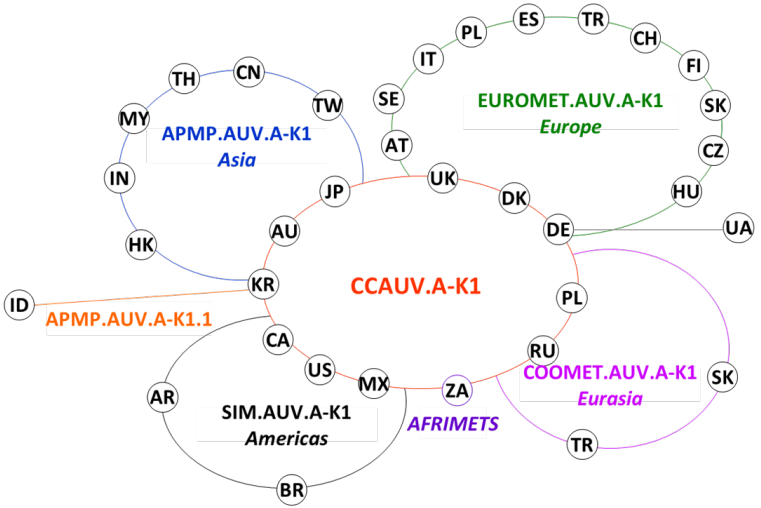
- $H^*(10)$
- $H_p(10)$

For fluence of:

- Neutron sources

CIPM key comparisons

- CIPM key comparisons: of international scope, are organized by Consultative Committees or the BIPM.
- Restricted to laboratories of Member States and normally members of the corresponding Consultative Committees.
- Deliver a “reference value” for the key quantity chosen.



Objective:
To test the principal techniques and methods in the field

BIPM Key Comparison Data Base (KCDB)

- **List of Calibration and Measurement Capabilities (CMCs) for CCRI Section 3**

- **Quantities for neutrons**
  - Emission rate (of neutron source)
  - Fluence/rate (thermal/fast/high energy)
  - Absorbed dose in Air/Water/Tissue

Quantity	Medium	Source
1 Emission rate	0 Not applicable	2 Mono-energetic neutrons
4 Fluence/rate	1 Air	3 Thermal neutron distribution
17 Absorbed dose/rate	2 Water	4 Wide energy range neutrons
	3 Tissue	11 Radionuclide sources
		12 High energy (>20 MeV) quasi-monoenergetic neutrons

Note:

1. *Institutes requesting new or updating existing CMCs in dose equivalent rate should convert them to the fluence/rate quantity using the corresponding conversion factor.*

2. *All the radionuclide sources for Neutron Measurements are now included in source 11 (Radionuclide sources), with the exception of D_2O moderated ^{252}Cf sources which should be included in 4 (Wide energy range neutrons). The indication of radionuclide should be given in the field "Source".*

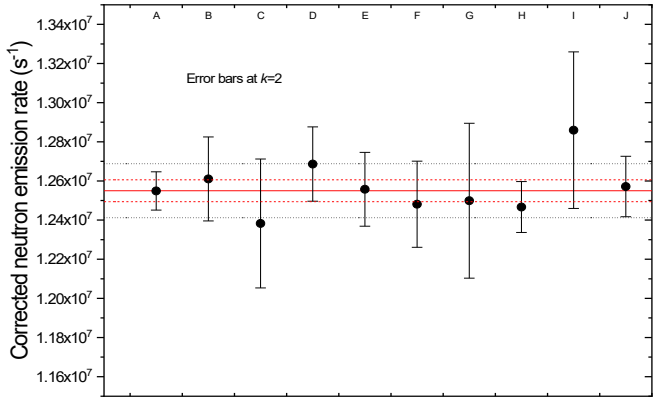
Energy ranges in neutron metrology	
E < 0.5 eV	Thermal
0,5 eV < E < 10 keV	Epithermal
10 keV < E < 20 MeV	Fast
E > 20 MeV	High Energy

Comparison Strategy

Committee	Date	Supporting documents (where applicable)	Notes
CCRI	7 June 2019	Minutes – 27th meeting Minutes – 23rd meeting CCRI/12-05	The period of validity of ionizing radiation comparisons under the CIPM MRA was reviewed and updated. A result from a comparison exercises may be used to support an application for new CMCs only for a limited time period. The time period starts from when the laboratory completed its measurement. The time period depends on the field: Section I: 10 years (15 years in exceptional cases) Section II: 15 years (20 years in exceptional cases) Section III: 10 years (15 years in exceptional cases) The CCRI Sections will decide whether an extension can be permitted.

Example: Finalised Key Comparison for Cf-252

- CCRI(III).K9.Cf.2016: ^{252}Cf neutron emission rate (Pilot: NPL)
  - Measurements finished
  - 10 participants in total, 9 use Mn bath technique
  - Cf-250 correction done by NPL



minimum uncertainties of participants ~ 0.5 % (*k=1*)

Participant	Measurement date
NPL	July 2016
CMI	January 2017
LNE-LNHB	March 2017
NIST	April 2017
NIM	September 2017
KRISS	July 2018
IRD/LNMRI	November 2018
NMIJ	January 2019
VNIIM	June 2019
NRC	March 2020
NPL	March 2021

International comparison of measurements of neutron source emission rate (2016-2021) - CCRI(III)-K9.Cf.2016
Metrologia, Volume 61, Number 1A
N J Roberts et al
2024 Metrologia 61 06001
DOI 10.1088/0026-1394/61/1A/06001

Key Comparisons for monoenergetic neutrons up to 20 MeV

2 Options:

- All participants come together with their reference instruments at one facility (K11)
- Sending around a transfer standard to all participants (K12)

CCRI(III)-K11 (2011/2012)

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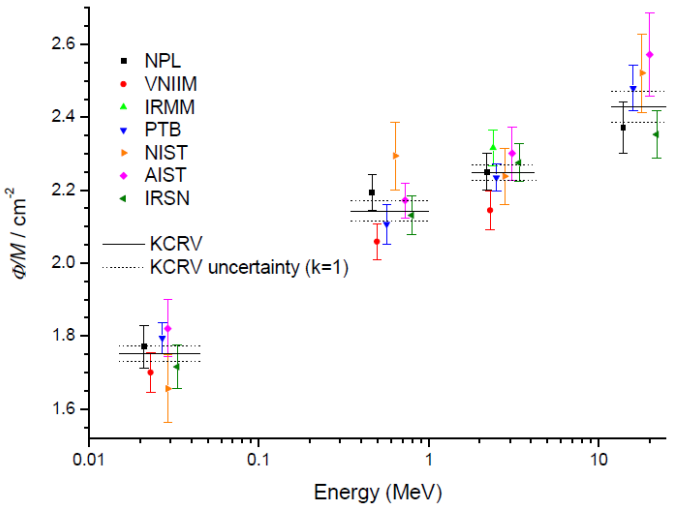

KCRV: u ~ (1-2) % (*k=1*)

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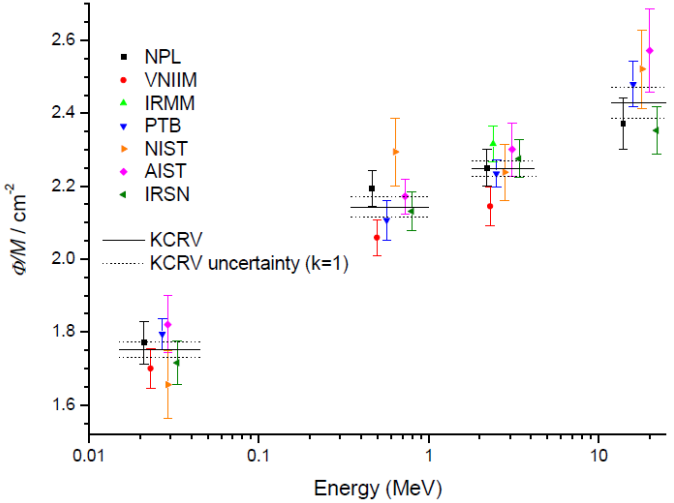


KCRV: u ~ (1-2) % (*k=1*)

CCRI(III)-K12 (started 2023)

- 9 participants
- 250 keV, 2.5 MeV (K11), 5 MeV (K10), 14 MeV, 19 MeV

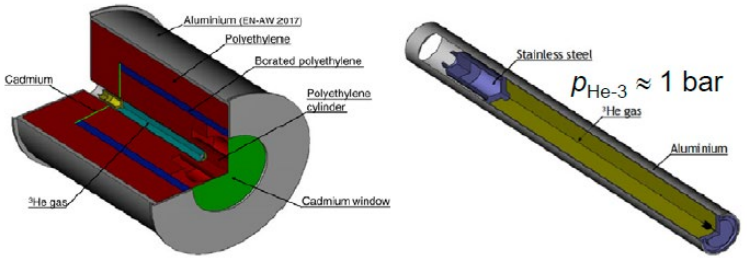


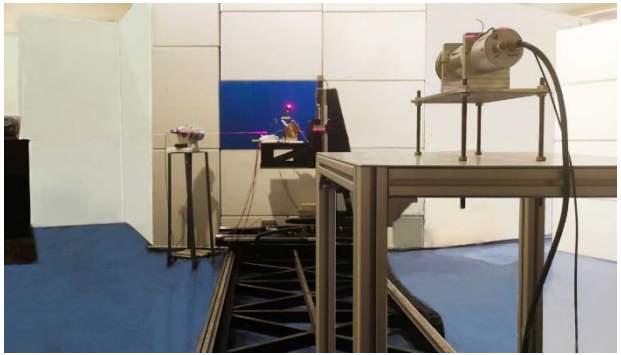
Figure 1. Design of the PLC moderator and ^{3}He tube as considered for the MCNP Monte Carlo simulations.

On-going Comparisons

- CCR(III)-K12 comparison: Monoenergetic neutron fields – Pilot: PTB
  - Energies: 250 keV (new), 2.5 MeV (K11), 5 MeV (K10), 14 MeV, 19 MeV (new)
- CCRI(III).S1- H*(10): (2017 – 2025) – Pilot: PTB
  - Circulation of 2 *SMARTREM* survey meters: one owned by PTB and one by IRSN
- CCRI(III)-K8.2024 comparison – Pilot: NIM & CMI
  - Comparison for thermal neutrons using a SP9 counter as transfer instrument
- CCRI(III).S2- Hp(10): 2022-2025 – Pilot : KRISS
  - Circulation of electronic personal dosemeters DMC3000 N (MIRION)

Challenges in high energy (> 20 MeV) neutron metrology

- Only few facilities worldwide, which are able to produce these neutrons
- They are all very different (spectrum, time structure, pulsing, etc.)
- No standards (ISO 8529 series covers < 20 MeV)
- No key comparisons and “primary standards” of NMIs like for < 20 MeV



CIAE – 70 MeV - 100 MeV

iTLABS – 30 MeV - 200 MeV