PSI Center for Corporate Services

Facilities and available instrumentation related to EMPANADE

(With focus on neutron radiation)

Department of Radiation Safety and Security (ASI), Paul Scherrer Institute (PSI)

2025-09-03, Kickoff meeting SwissELITE Detector Project 3

Outline

- Facilities
  - Reference continuous fields
  - Pulsed fields
- Available Instrumentation
  - Active
  - Passive
- General remarks

Facilities

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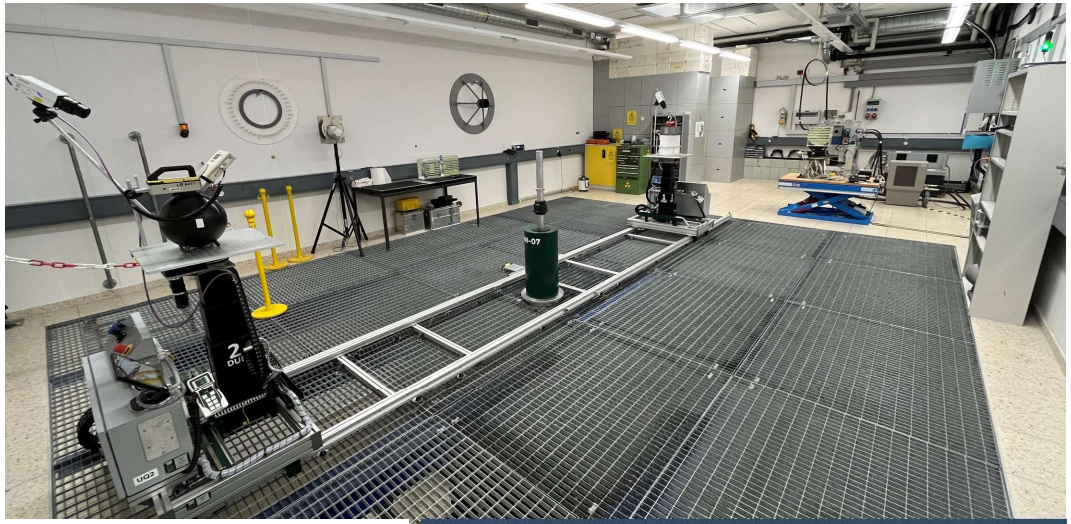
Continuos fields: Neutron Sources

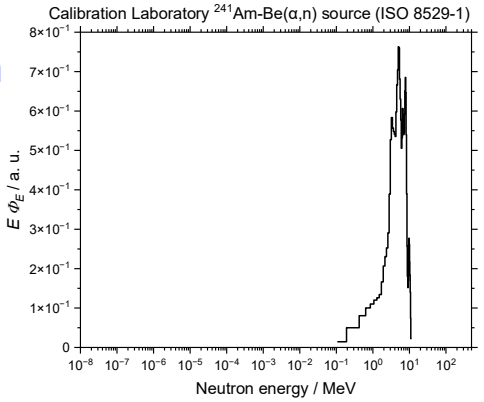
Calibration laboratory:

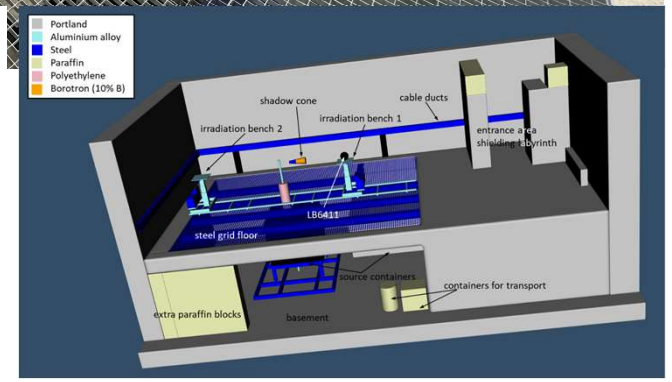
- ^{241}AmBe, ^{252}Cf(bare), ^{252}Cf(D_2O_{mod})
  - Limited energy range
- Reference quantity: *H**10
  - Spectral distribution from simulations available
- Continuous dose rates: ~mSv/h

- Good to verify detector calibration during intercomparison exercises

- ^{60}Co, ^{137}Cs



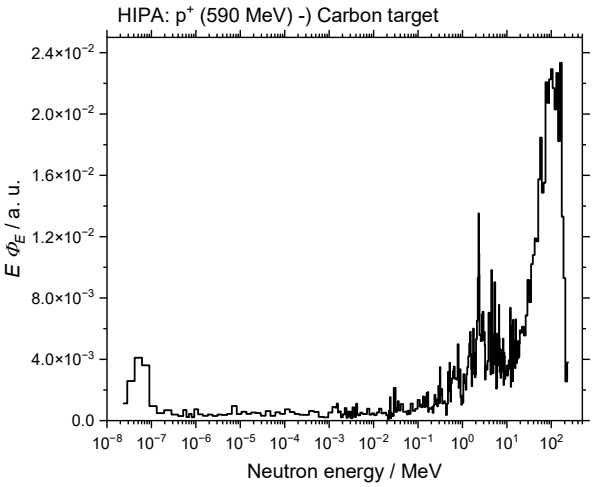


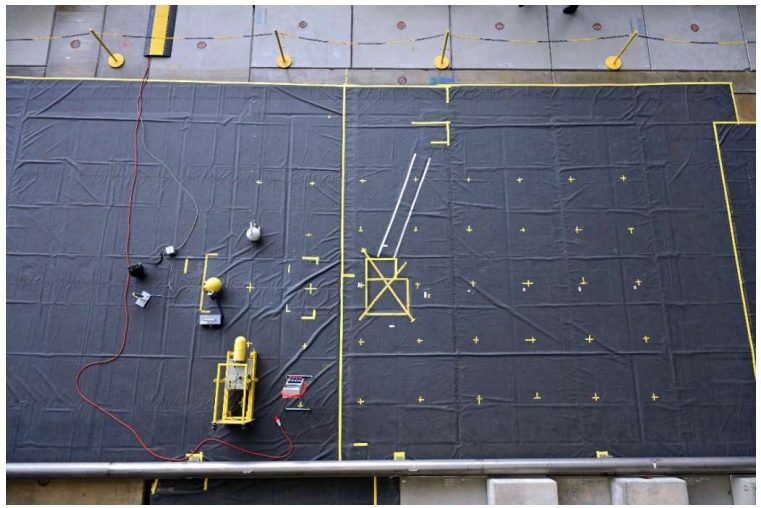


Continuous fields: High-energy neutrons

PHAIDRA*: Suitable for the characterization of neutron detectors (similar to the “CERF” field at CERN)

- Characterized by **measurements** (Bonner sphere spectrometer) and **simulations**
- Available dose rates: < 80 µSv/h



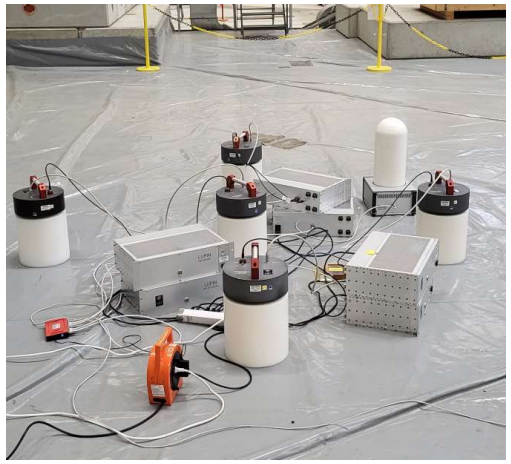


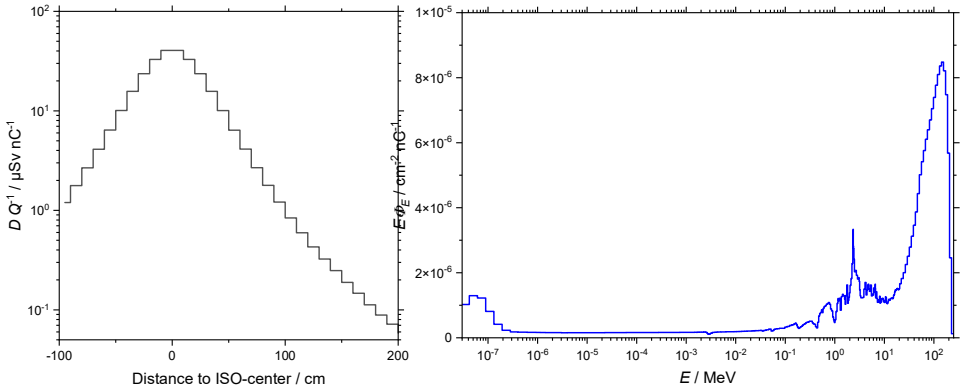
*PSI High-energy Area for Instrument testing and Dosimetry of RAdiation

Pulsed with high dose rates (FLASH)

- Measurements outside the shielding of a proton irradiation Gantry
  - Variable dose rates (up to Sv/h)
  - Pulse length: ms
  - Clinical protocols need to be used: Limited flexibility in varying parameters
  - Normalization: Proton current monitor in the beam delivery system

- Calibrated by **measurements (*H**10)** and **Monte Carlo simulations**
  - Neutrons with energies up to 250 MeV
- Field with high gradient



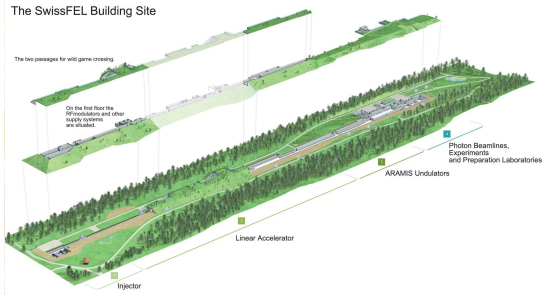


Pulsed with short pulse length (SwissFEL)

SwissFEL is the Swiss X-Ray free-electron Laser accelerator facility of PSI

Beam characteristics

- Electron energy: up to 5.8 GeV
- Charge per pulse: 10 - 200 pC/bunch
- Repetition rates: up to 100 Hz, single shot feasible
- Pulse length: 1- 20 fs



- Measurements feasible for operation on a beam stopping device
  - Characterized by Monte Carlo simulations
    - Dose rates up to 200 µSv/h
  - Stable beam monitoring

Available Instrumentation

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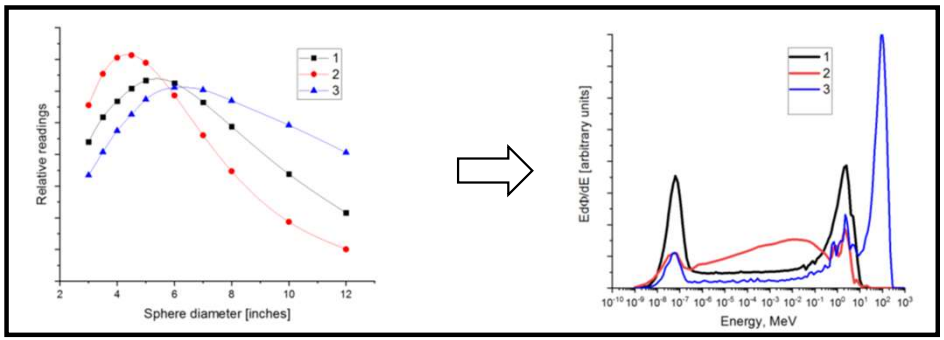
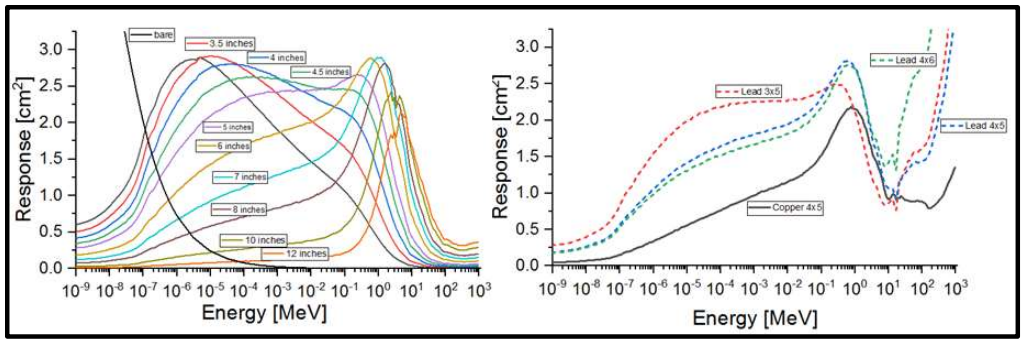
Active neutron spectrometry

- Extended Range Bonner Sphere Spectrometer
  - 15 different moderator spheres
  - Measurement of different moderators using **stable** and **normalized** fields
  - Characterized by Monte Carlo simulations, verified in reference fields (PTB)

→ **Major challenge:** deconvolution of the data to obtain the neutron spectrum

→ **Currently only suitable for steady fields**

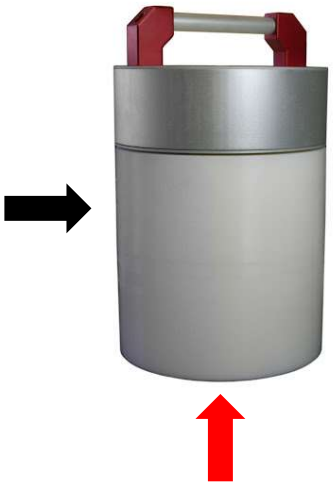


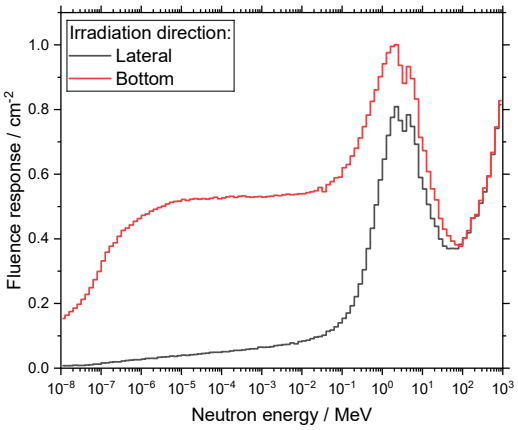


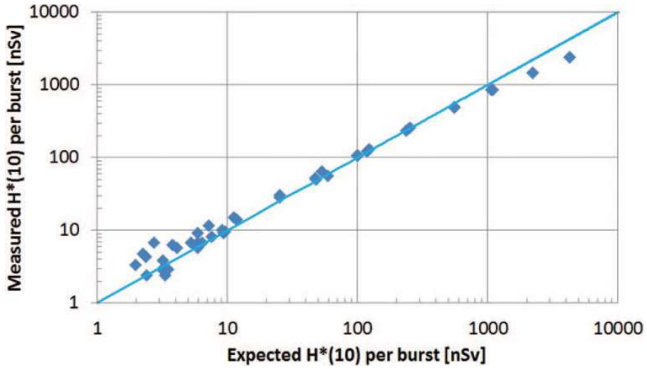
Active neutron survey instrument (for pulsed fields)

LUPIN 5401 BF3-NP (ELSE Nuclear)

- Routinely used at PSI (More than 65 instruments)
- Calibration: Relative to the field produced by ^{241}AmBe
- Suitable for measuring neutrons up to a few GeV
- Cylindrical moderator: Irradiation direction changes dose indication
- Integration period: 50 ms
- Maximal dose per pulse: 7.5 µS*
- Radiation sensitive electronics separated from detector unit







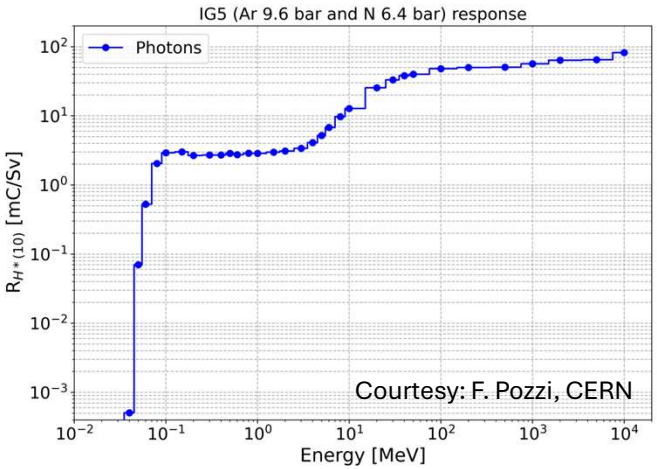
*Manufacturers‘ specification

Active photon survey instrument (for pulsed fields)

NAUSICAA ICT-**PF**

- Pressurized ion chamber detector
- Calibration: Relative to the field produced by ^{137}Cs
- Energy dependent response
  - Simulations show comparable sensitivity to other particle types

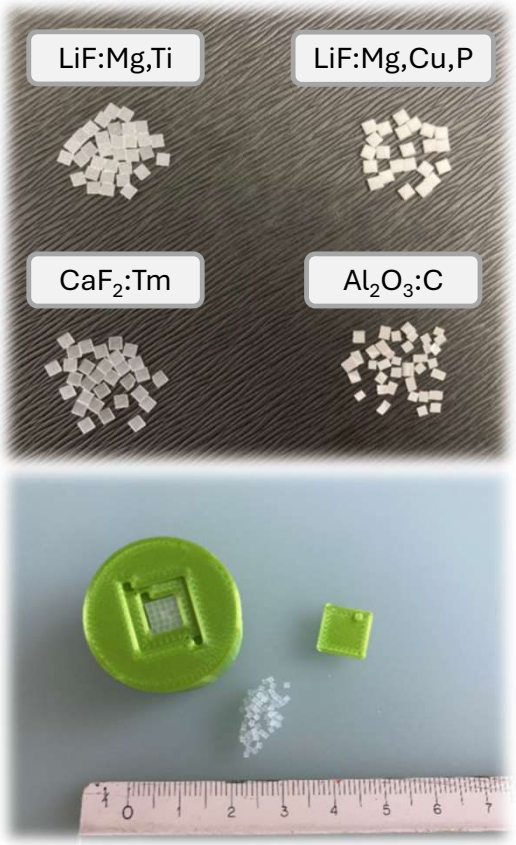
- Integration period: 1 s
- Dose rate range: 10 nSv/h to100 mSv/h*
- Radiation sensitive electronics separated from detector unit

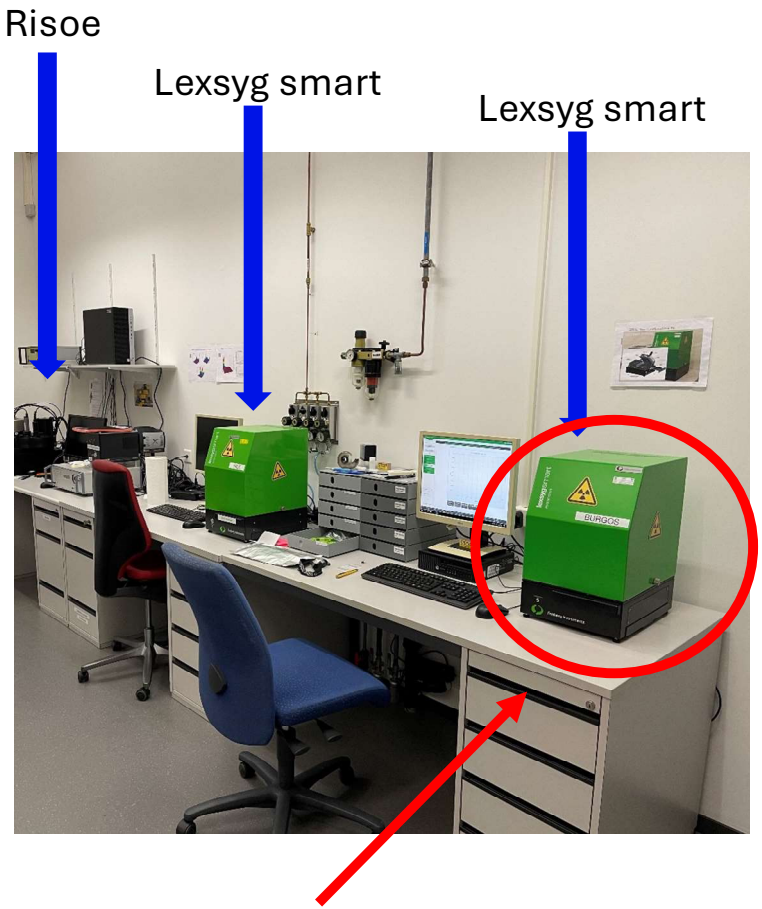


*Manufacturers‘ specification

Passive photon dosimetry: Luminescence dosimetry

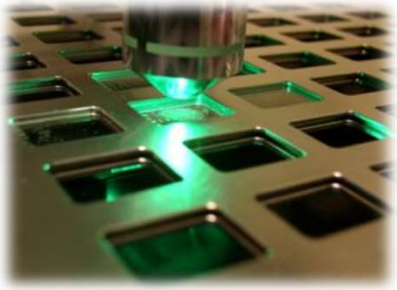
- Different materials available
- Advantages:
  - Precise
  - Tissue equivalent
  - Small
  - **No dose rate dependence**
  - Not affected by magnetic field

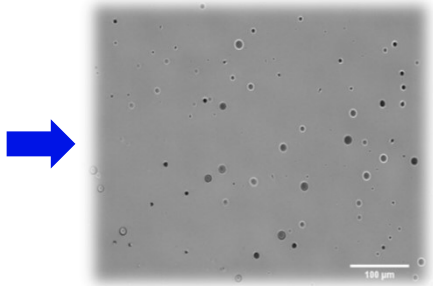


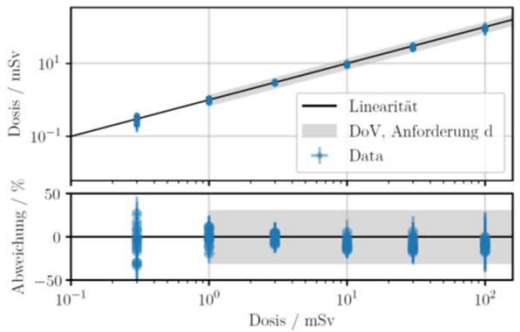


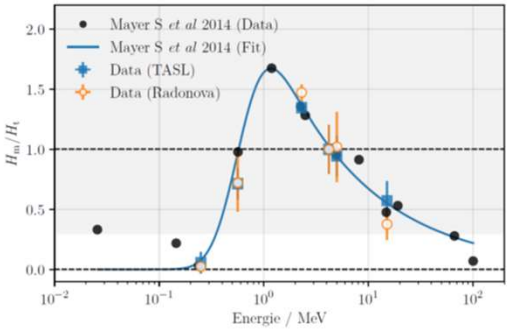
Passive neutron dosimetry (PADC*)

- Nuclear track detectors
- Evaluation needs extensive **chemical** and **optical** evaluation
- Lower detection threshold: 100 µSv with limited dose range
- Calibration
  - Relative to **the field produced by ^{241}AmBe**
  - **Energy dependent response**









Christensen, J. TM-96-23-1278 (2024), Mayer et al (2014) Radiat. Prot. Dosim. 161, 82-85 (2014)

***: Poly-Allyl Diglycol Carbonate**

General remarks

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Final remarks

- Focus PSI: Active neutron measurements

- Passive dosimetry:
  - Photons: No difference to ELI
  - **not included** in the current budget

- Measurement Campaigns:
  - Resource intensive (personal and technical)

    -) Advance detailed planning necessary
  - Availability of facilities **may be limited** or to be **changed on short notice**
  - Survey instruments with different energy dependencies:

    -) Definition of reference values crucial

PSI Center for Corporate Services

Thank you for your attention

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