Validating nuclear data for lead with shielding benchmarks

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OUTLINE

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1. Background

- **Lead is one kind of coolant material in fast reactor. It also can served as shielding material.**
- **The nuclear reaction data for Pb are both important in criticality and shielding transport calculations.**
- **Criticality benchmark testing of CENDL-3.2 show both positive and negative k_{eff} bias in lead reflected criticality benchmarks HMF057.**
  - Pb is one of top 10 materials that contributed to the total criticality k^2 most.
- **Shielding benchmark can show and even amplify the defects in nuclear data only related to the sample tested.**
- **To validate the reaction data for lead, the evaluated data from major libraries were tested with the JAERI/FNS and ALARM-Cf-Pb experiments.**

2. Simulation and analysis method

- **Nuclear data preparation**
  - Njoy99.396 + local patch c10.
  - CENDL-3.2, ENDF/B-VIII.0, JEFF-3.3, JENDL-4.0, BROND-3.1.
- **Transport calculation**
  - MCNP5 + 10^7 history
  - No variance reduction technology was applied in calculation.
- **Sensitivity of shielding benchmark**
  - Decay of the neutron flux in the media follows the law of indices.

Neutron flux $\phi = \phi_0 \exp\left(-\Sigma_t x\right)$

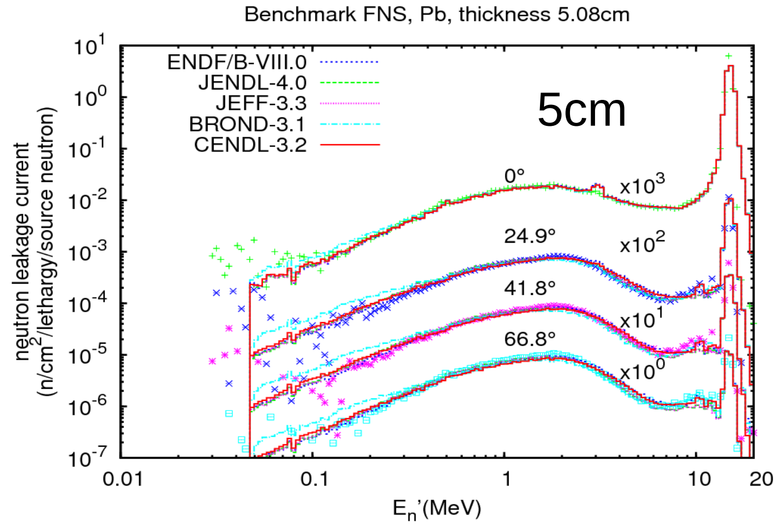
Sensitivity of neutron flux $\dfrac{d\phi/\phi}{d\Sigma_t/\Sigma_t} = -x\Sigma_t = -\dfrac{x}{\lambda_t}$

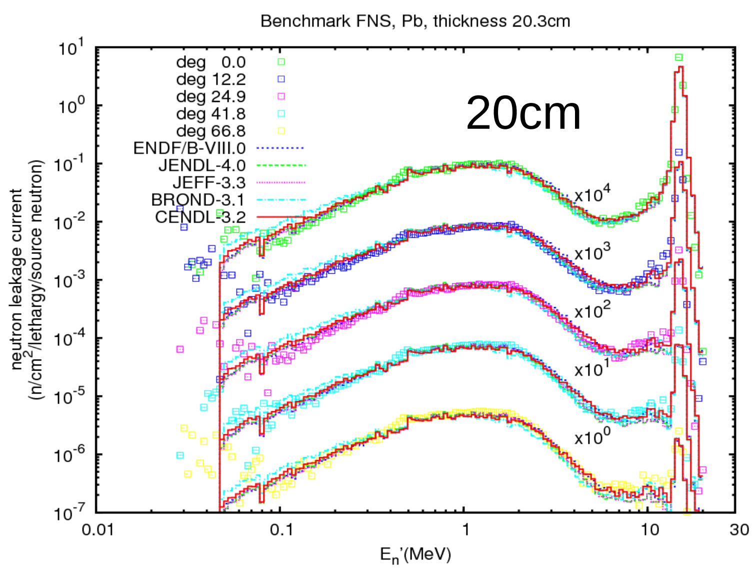
$$\text{When } x = \text{Constant}, \ \frac{d\phi}{\phi} = -x d\Sigma_t$$

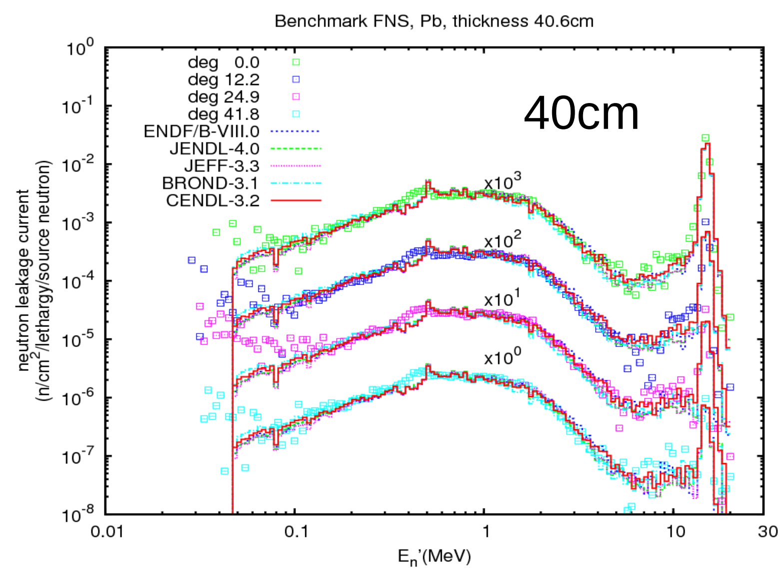
$$\frac{d\phi/\phi}{d\Sigma_t/\Sigma_t} \approx -\frac{x}{\lambda_s}, \ (weak\ absorb)$$

3. Result of the JAERI/FNS slab

- **Similar results based on different evaluation library.**
- **Under prediction of neutron fluxes were found around 4MeV and from 8-14MeV.**
- **Bias below 0.1MeV are ignored in this work.**

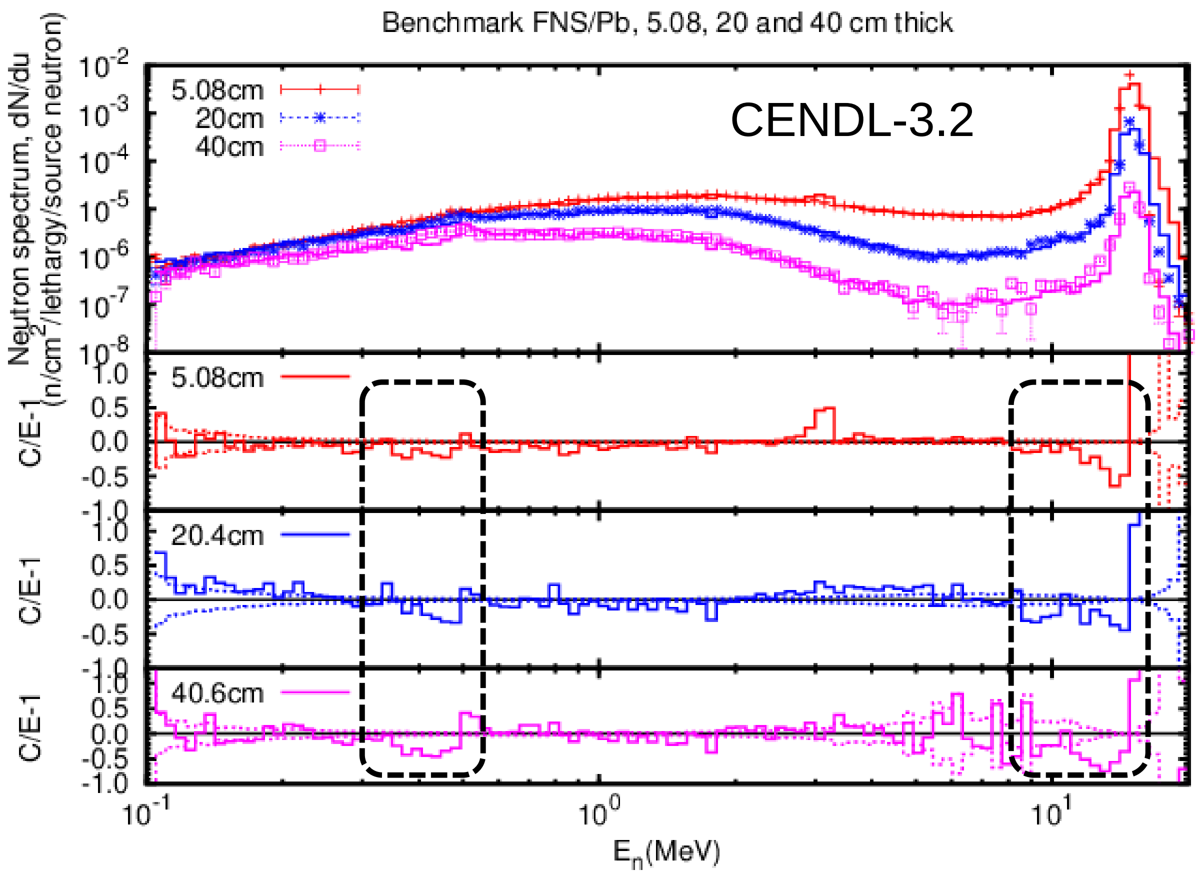






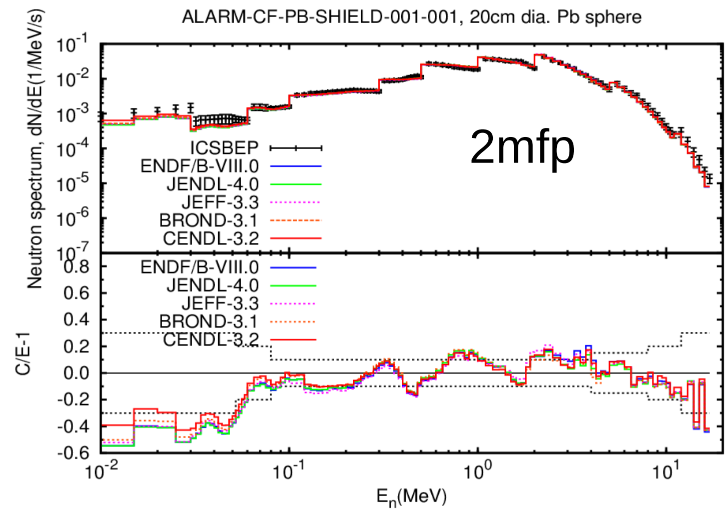
3. Result of the JAERI/FNS slab

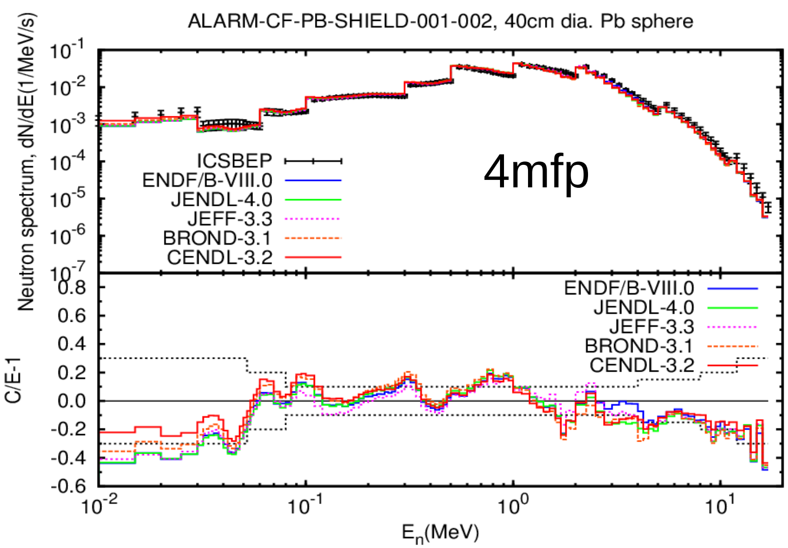
- **Bias related to thickness**
  - 0.366-0.494MeV and 8.13~14.8MeV are corresponding to (n,el) and (n,inl) reaction separately.

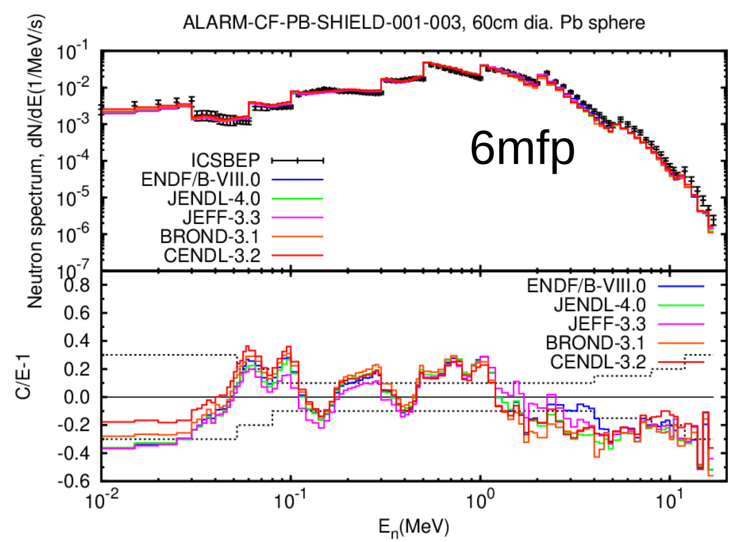


4. Result of the IPPE sphere

- **ENDF/B-VIII.0 gives the best results.**
- **Both under estimation and over estimation were found.**
  - <0.05MeV and >2MeV
  - 0.05~0.1MeV and 0.5~1MeV

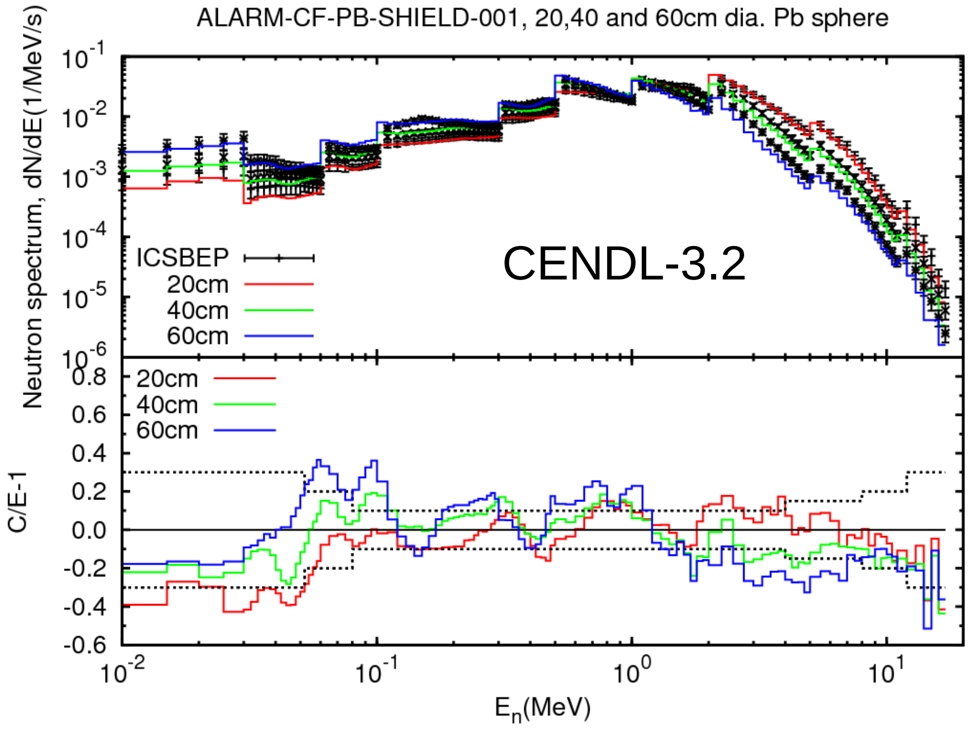






4. Result of the IPPE sphere

- **Bias related to thickness**
  - 1.2-8.4MeV, underestimation of neutron flux against thickness increasing were caused by overestimation of (n, inl) scattering.
  - Below 1MeV, overestimation of neutron flux were partially caused by overestimation of (n,inl) cross sections.



5. Discussion and Summary

- **Pb evaluations from 5 major library were validated with shielding benchmarks, similar performance were shown in comparison.**
- **The sensitivity of leakage neutron flux to macroscopic total cross section was deduced, which equals the number of MFP for the sample thickness.**
  - Thicker sample, higher sensitivity.
  - When absorb reaction is weak, scattering reaction will play main role.
- **Validation results of FNS and the IPPE sphere show that**
  - Above 1.2 MeV, (n,inl) cross sections were underestimated.
  - Around 0.366-0.494MeV, (n,el) cross sections were underestimated. Resonance parameters for lead need to be improved.

Thank you for your attention !

Questions?

2 Benchmark and calculation

- **JAERI/FNS**
  - Angular neutron flux spectra leaking from lead slab induced by D-T neutron source were measured at the JAERI in 1990's.

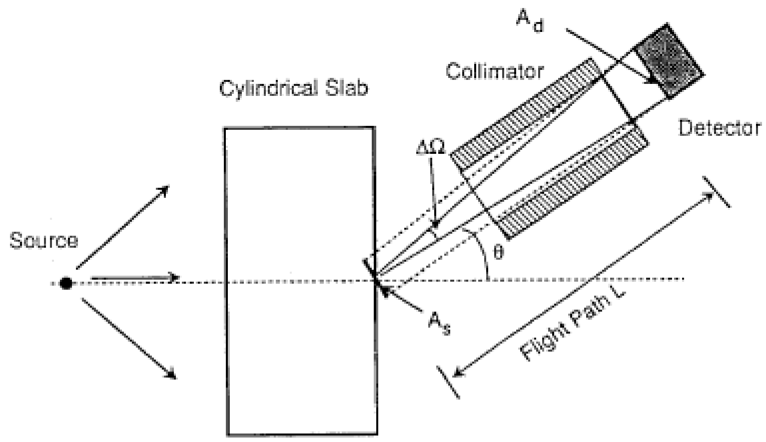


Fig. Diagram of FNS experiment

  - 3 samples with a thickness of 5.08, 20.3 or 40.6cm were used in the experiment. These thickness are corresponding to 1, 4 and 8 mfp of 14 MeV neutron in lead separately.
  - The spectra were measured in 0°, 12.2°, 24.9°, 41.8° and 66.8°.

2 Benchmark and calculation

- **ALARM-CF-PB-001**
  - The spectra of neutrons and gamma-ray photons flowing away from lead spheres of different diameters induced by a ^{252}Cf source placed at the center were study at the IPPE in 1980’s.
  - Experimental results for 3 sphere with diameters 20, 40 and 60cm were given in the ICSBEP Handbook.
  - The thickness of 20, 40 and 60cm dia. sphere are corresponding to 2, 4, 6 mfp of fission neutron in lead separately.

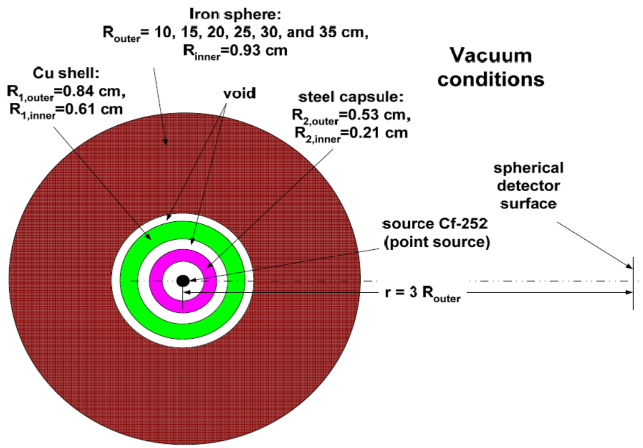


Fig. Diagram of ALARM-CF-FE-001 experiment