EFFDOC-1004

# TASK TTMN-002

# VALIDATION OF FENDL-2.1 and JEFF-3.1 LIBRARIES FOR FUSION APPLICATIONS

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**FNG Benchmark experiments for FENDL-2.1 / MC validation in the frame of ITER Project Management and Quality Program: Quality Assurance in Neutronic Analyses** (EFFDOC-964)**:**

- **Bulk shield experiment** (inboard shield, stainless steel & water)
- **Streaming experiment** (shield with streaming channel, stainless steel & water)
- **Silicon Carbide (SiC) block**
- **Tungsten block**
- **Breeder blanket (Be / $Li_2CO_3$) experiment**

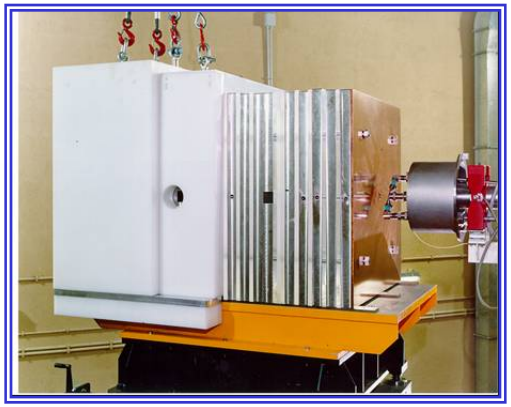
**➔ now also JEFF-3.1 analysis**

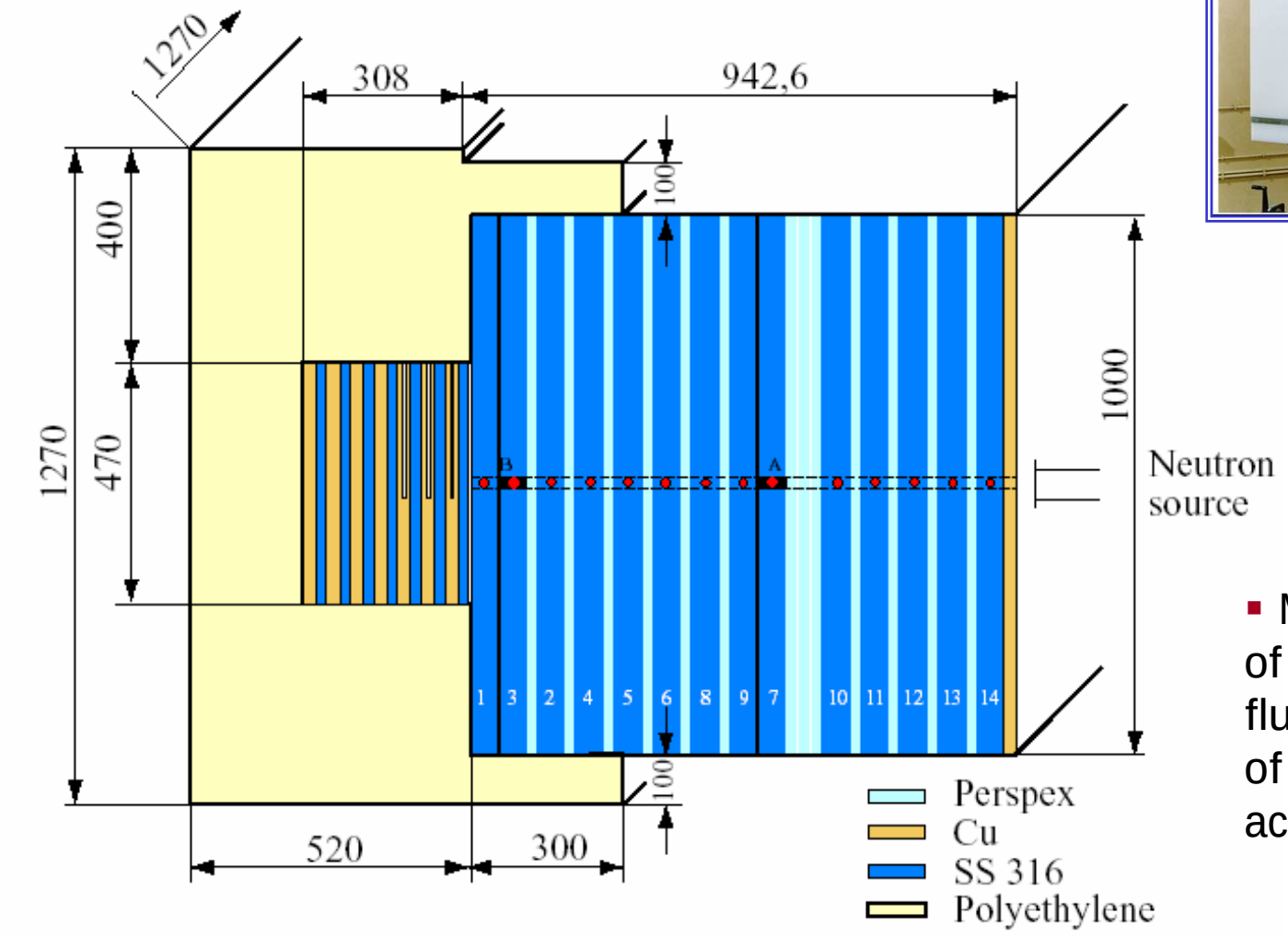
## Main elements in benchmark experiments — *Data origin*

| Materials | EFF-3.0/3.1 | JEFF-3.1 | FENDL-1.0 | FENDL-2.0 | FENDL-2.1 |
|---|---|---|---|---|---|
| Fe-56 | EFF-3.1 | EFF-3.1 | ENDF/B-VI.1 | EFF-3.0 | EFF-3.1 |
| Cr-52 | EFF-3.0 | EFF-3.1 | ENDF/B-VI | ENDF/B-VI | ENDF/B-VI.8 |
| Ni-58<br>Ni-60 | EFF-3.1<br>EFF-3.0 | EFF-3.1<br>EFF-3.1 | ENDF/B-VI.1 | ENDF/B-VI.8<br>ENDF/B-VI.8 | EFF-3.1<br>ENDF/B-VI.8 |
| W-182,3,4,6 | EFF-3.1 | JENDL-3.3 | ENDF/B-VI | JENDL-FF (W-nat) | ENDF/B-VI.8 |
| Li-6<br>Li-7 | | ENDF/B-VI.3<br>EFF-2.4 | ENDFB VI.1<br>ENDFB VI | ENDF/B-VI<br>ENDF/B-VI | ENDF/B-VI.8<br>ENDF/B-VI.8 |
| Be-9 | EFF-3.0 | EFF-3.1 | ENDF/B-VI (C-nat) | JENDL-FF | JENDL-FF |
| C-12 | | ENDF/B-VI (C-nat) | ENDF/B-VI.1 (C-nat) | JENDL-FF | JENDL-FF |
| O-16 | | ENDF/B-VI | ENDF/B-VI | JENDL-FF | ENDF/B-VI.8 |
| Si-28 | EFF-3.0 | JENDL-3.3 | BROND-2 | ENDF/B-VI.8 | ENDF/B-VI.8 |

# *Bulk Shield Experiment*

Mock-up of the ITER inboard first wall/shielding blanket/vacuum vessel/toroidal magnet

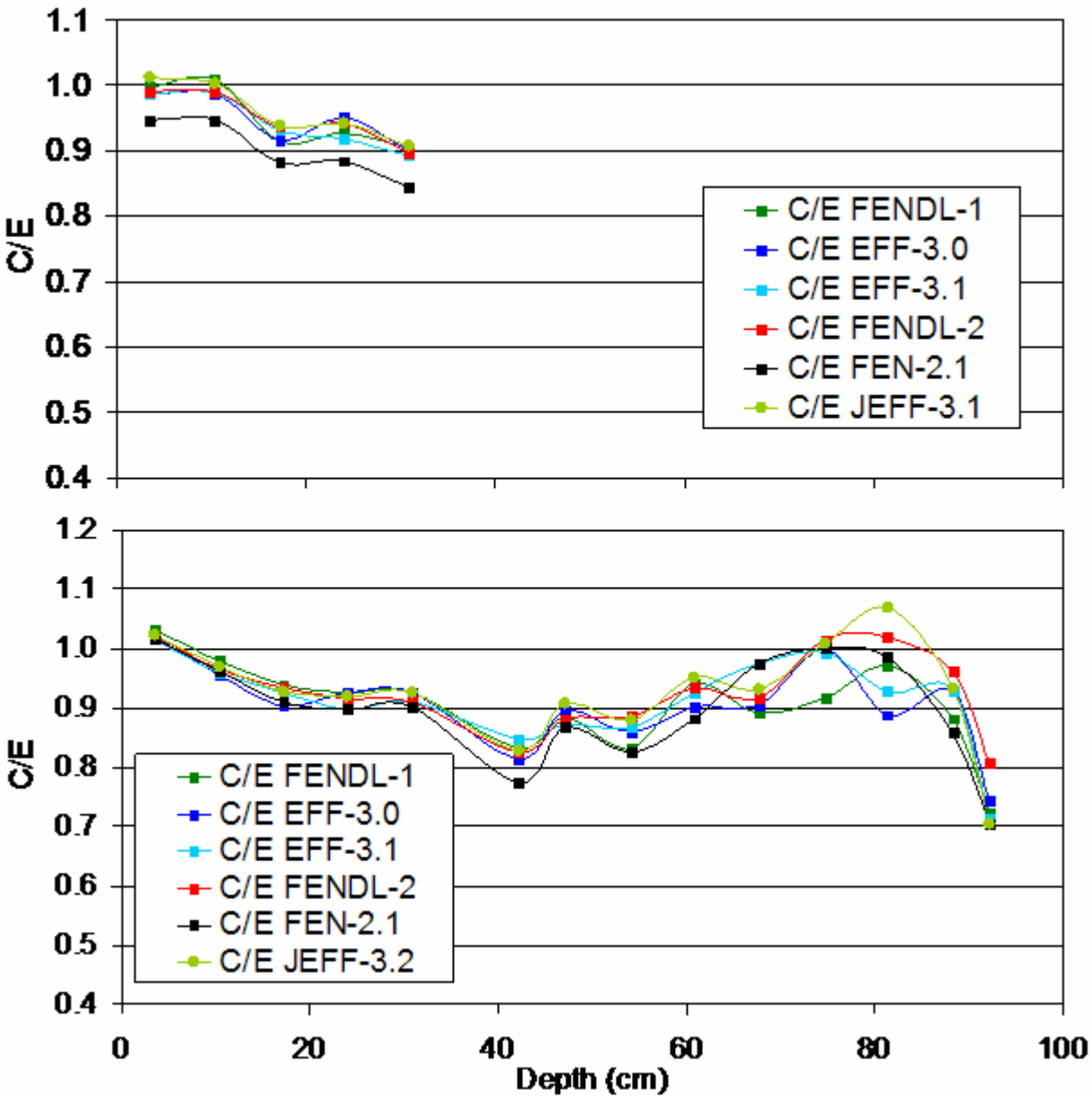





- Measurements of the neutron flux as a function of depth by activation foils

## *Validation of FENDL-2.1 & JEFF-3.1*

## *Bulk Shield Experiment*



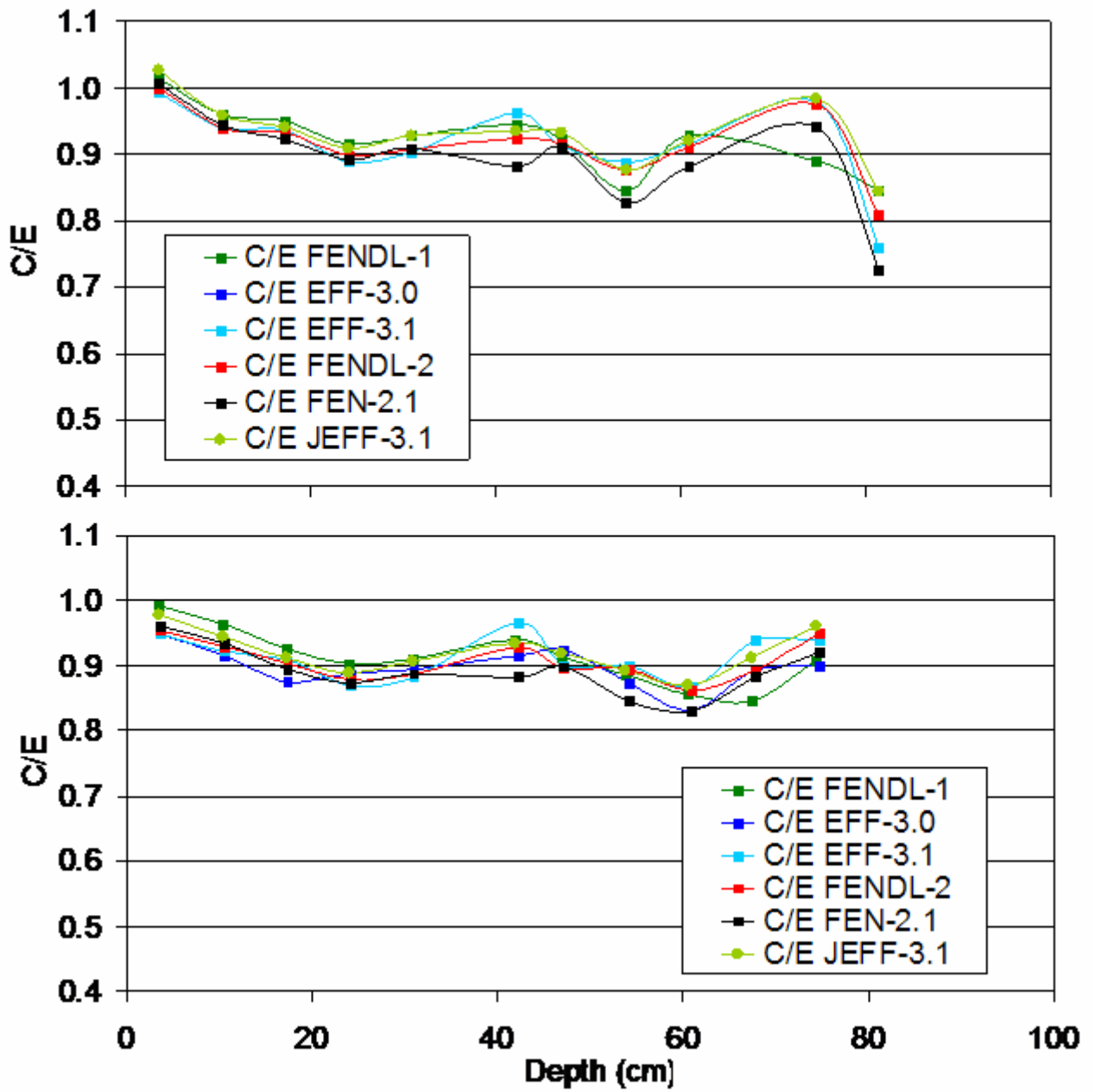

**E> 10 MeV**

**Ni-58(n,2n)**

**Nb-93(n,2n)**

## *Validation of FENDL-2.1 & JEFF-3.1*

## *Bulk Shield Experiment*



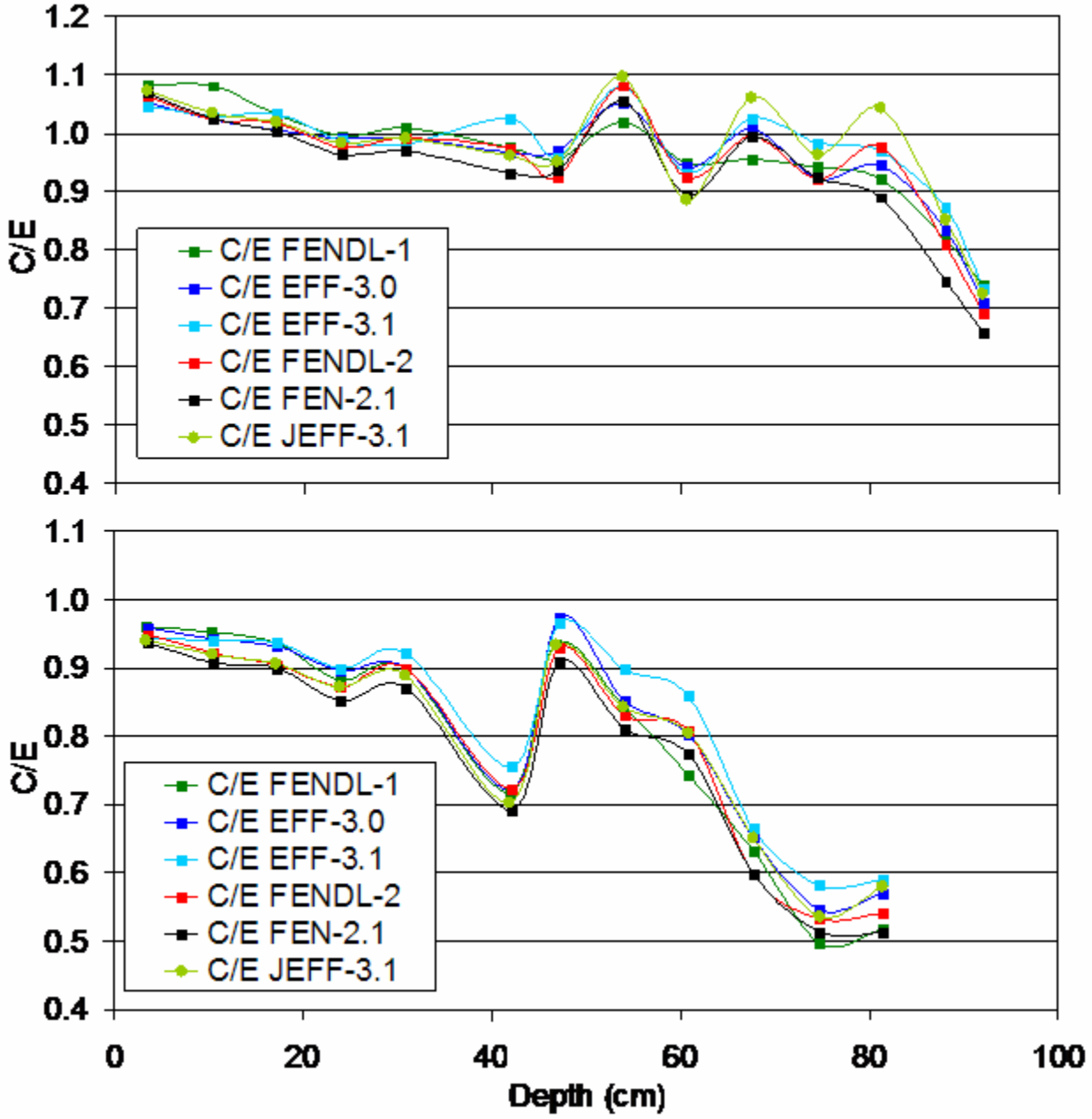

**E> 3 MeV**

**Al-27(n,a)**

**Fe-56(n,p)**

## *Validation of FENDL-2.1 & JEFF-3.1*

## *Bulk Shield Experiment*



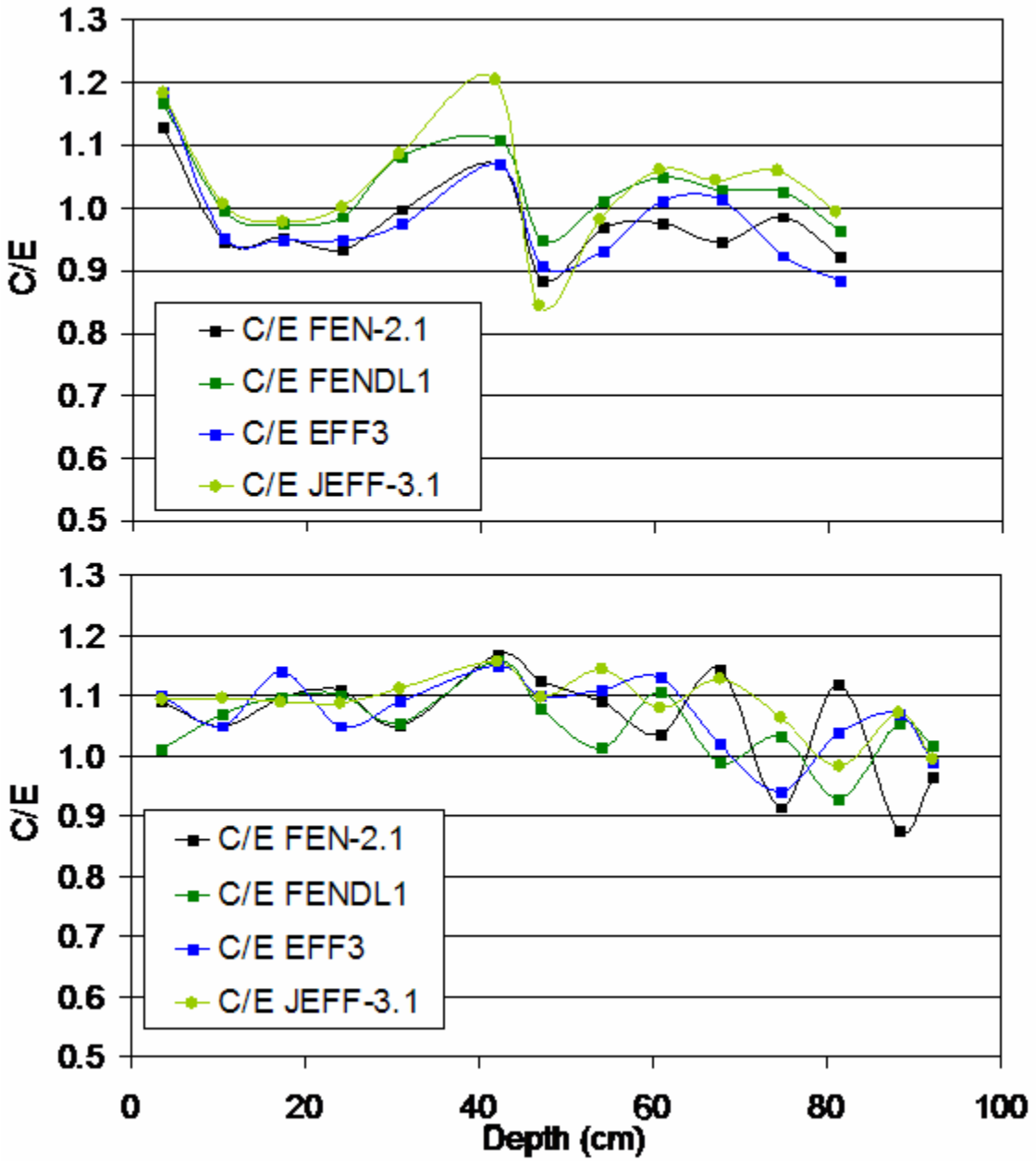

**E> 0.8 MeV**

**Ni-58(n,p)**

**In-115(n,n')**

## *Validation of FENDL-2.1 & JEFF-3.1*

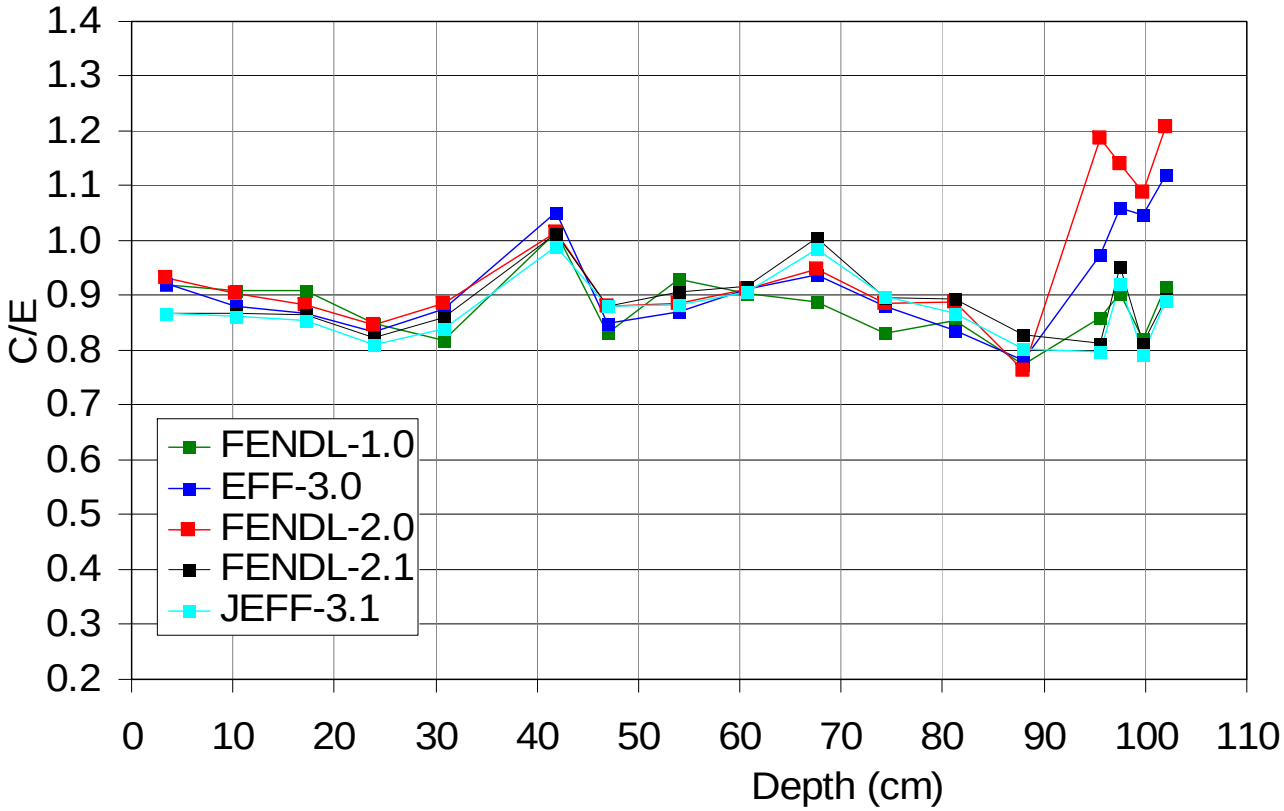
## *Bulk Shield Experiment*




**E ≈ eV**

**Mn-55(n,g)**

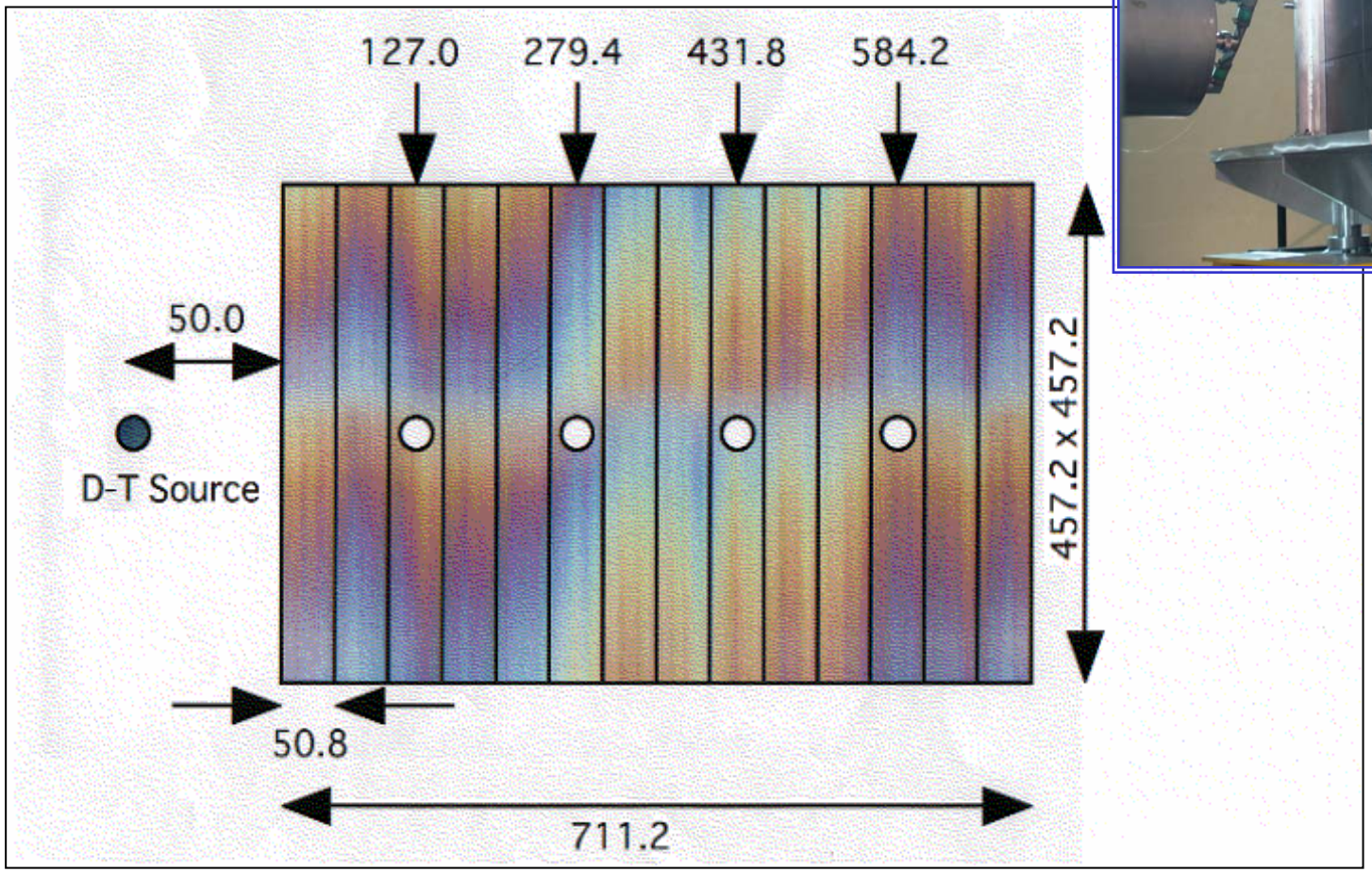
**Au-197(n,g)**




**Nuclear Heating in stainless steel and copper**

# *SiC Experiment*

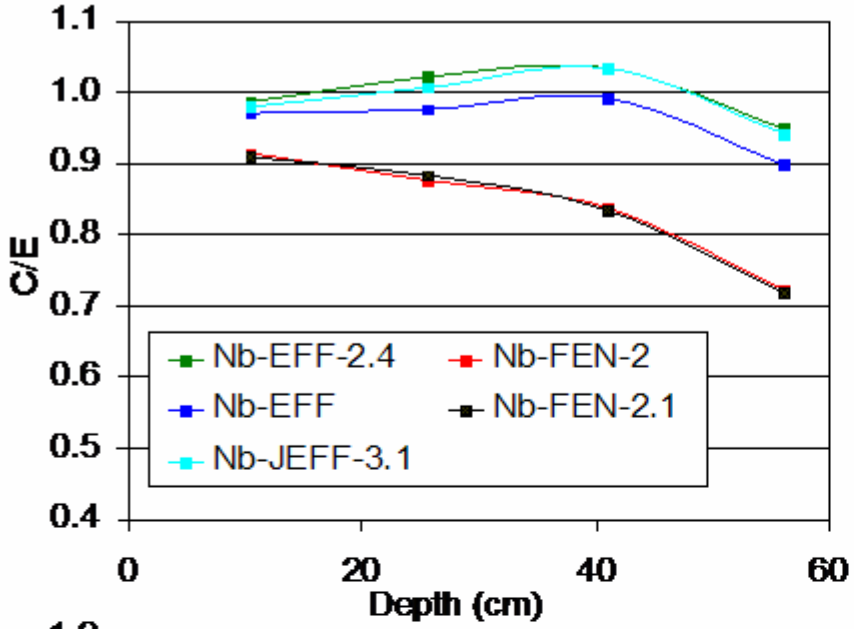
Silicon Carbide block (SiC, advanced low-activation structural material)

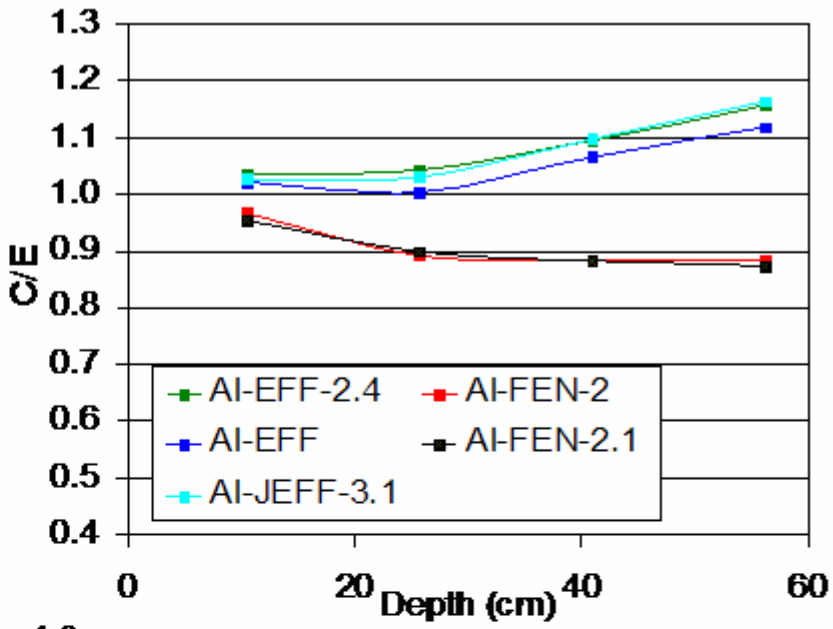


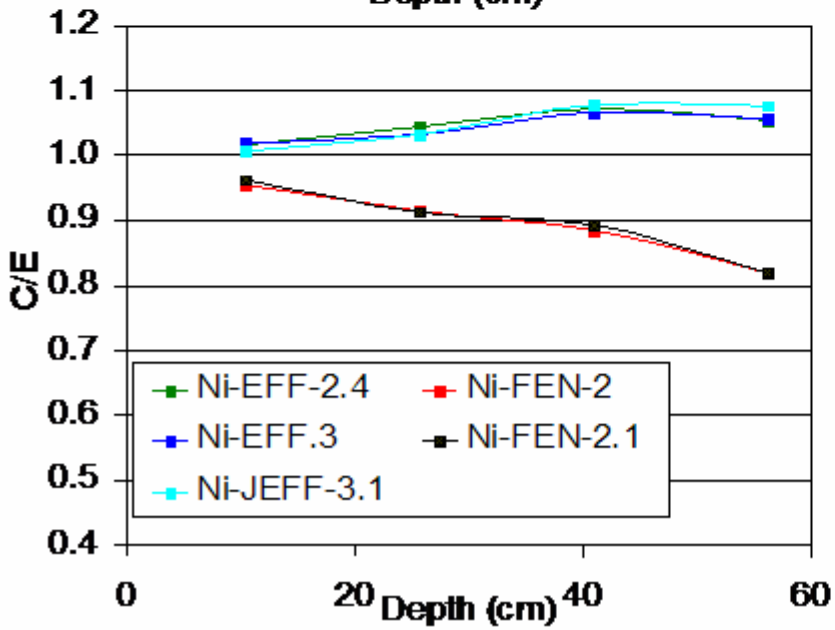

- Measurements of the neutron flux in four positions at different depths by activation foils

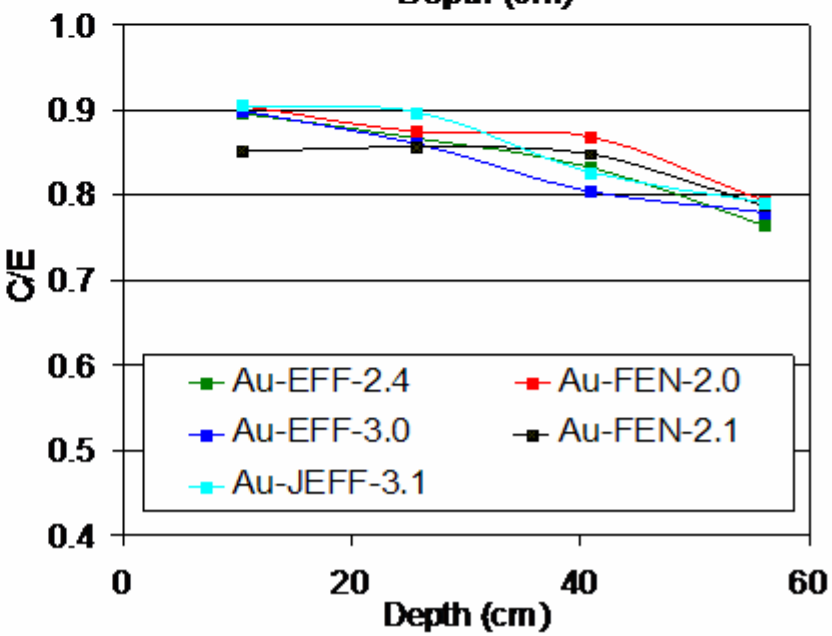
## *Validation of FENDL-2.1 & JEFF-3.1*

## *SiC Experiment*



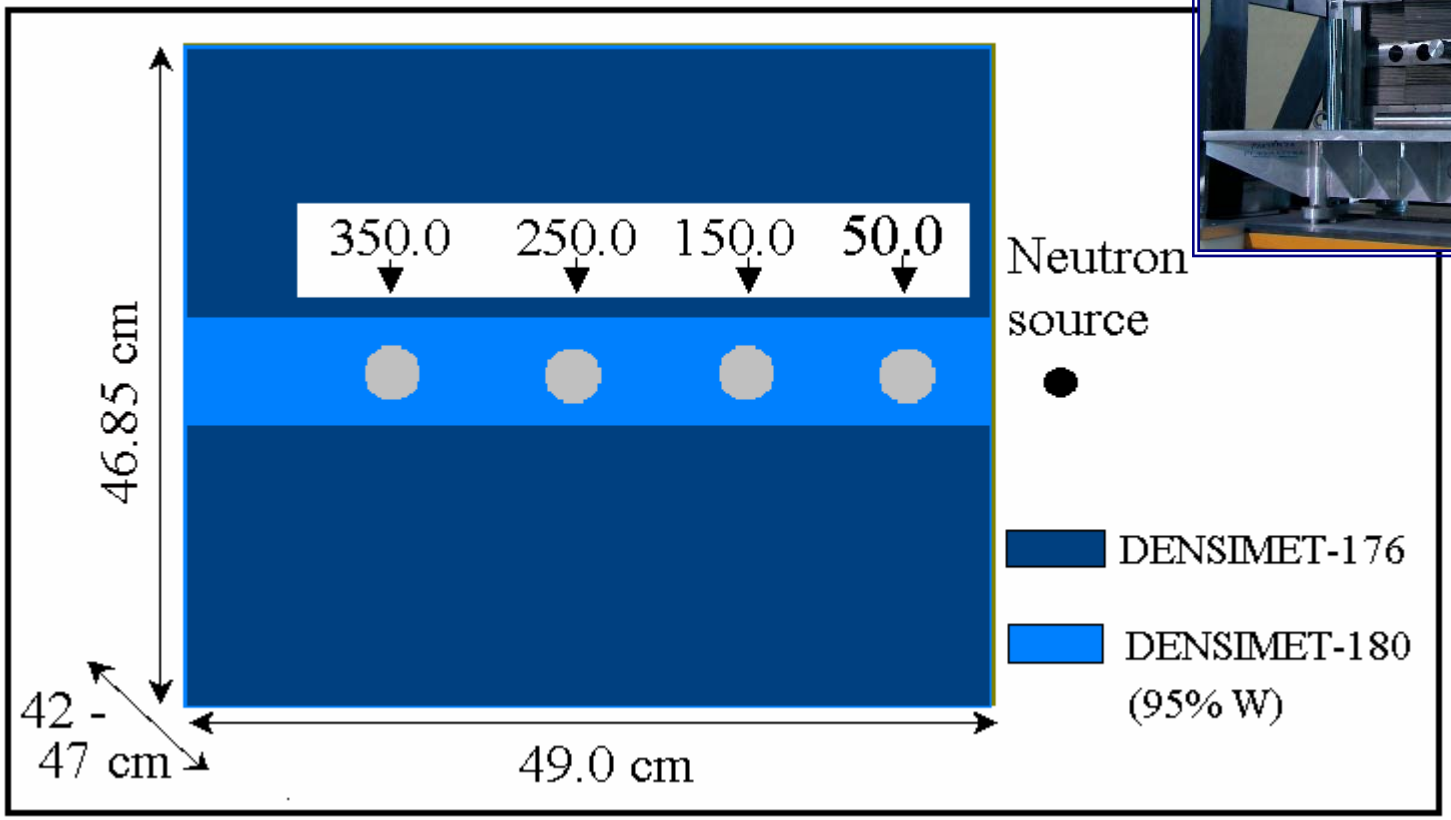



# *Tungsten Experiment*

Tungsten block (armour material for plasma facing components)

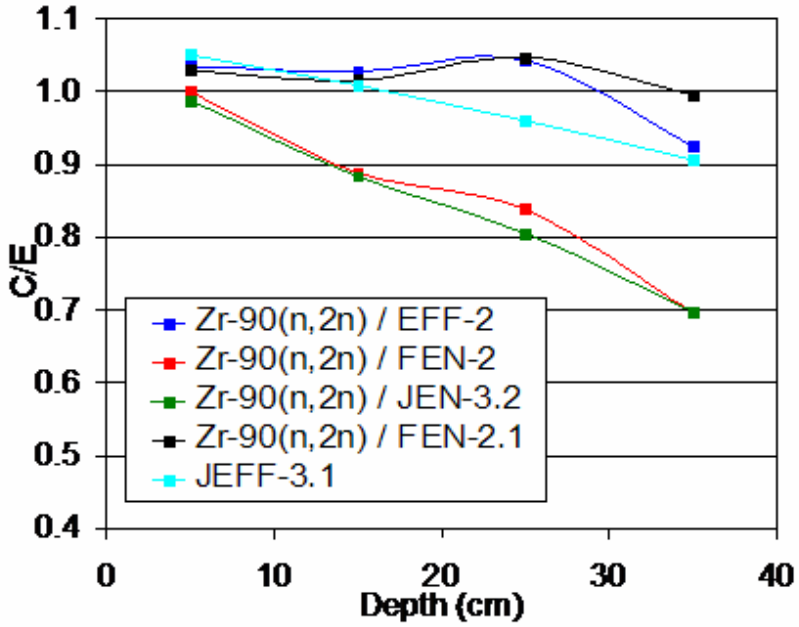



DENSIMET-176 (93.2%w W, 2.6%w Fe, 4.2%w Ni, 17.70 g/cm$^3$).
DENSIMET-180 (95.0%w W, 1.6%w Fe, 3.4%w Ni, 18.075 g/cm$^3$)

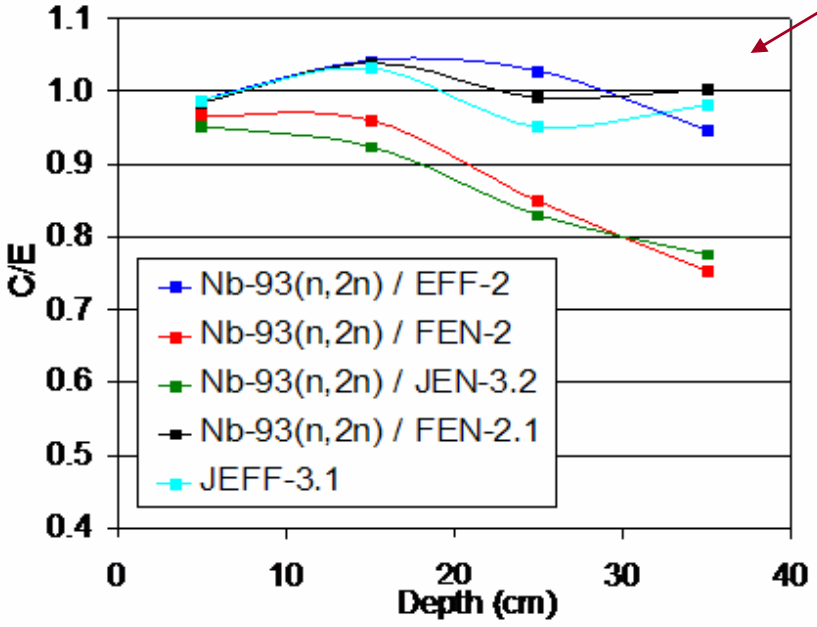
- Measurements of the neutron flux in four positions at different depths by activation foils

**E > 10 MeV**

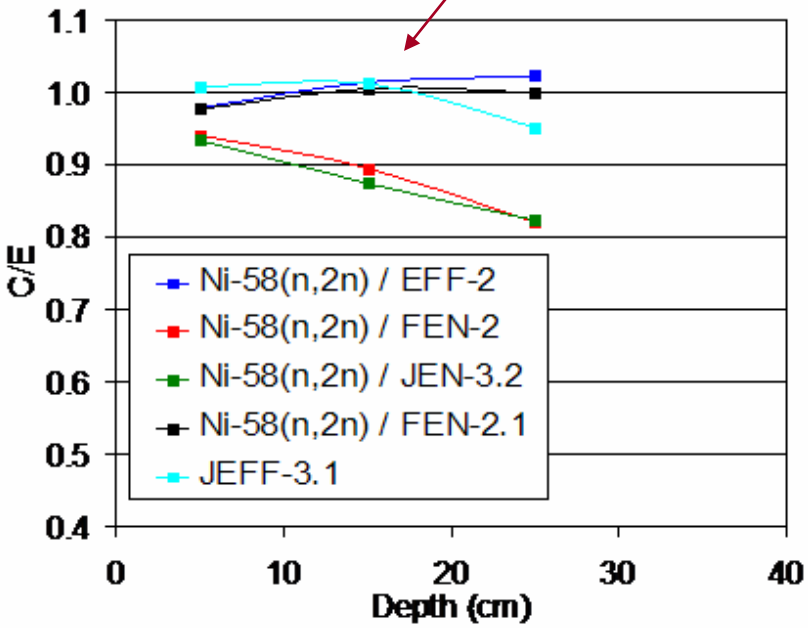
**Zr-90(n,2n)**




**Nb-93(n,2n)**

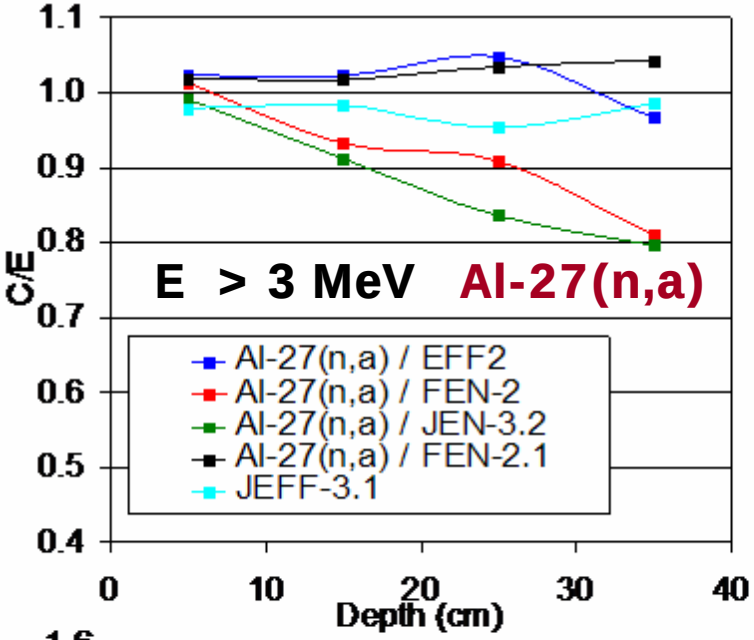


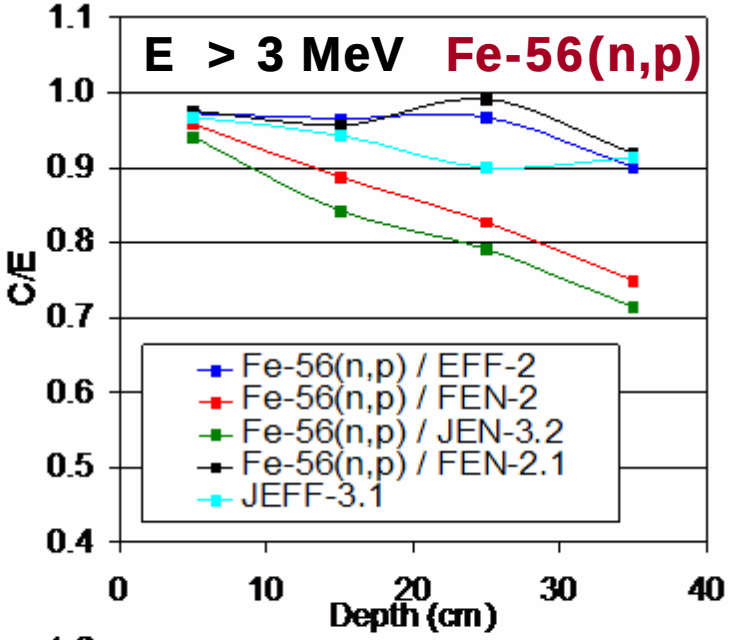

**Ni-58(n,2n)**

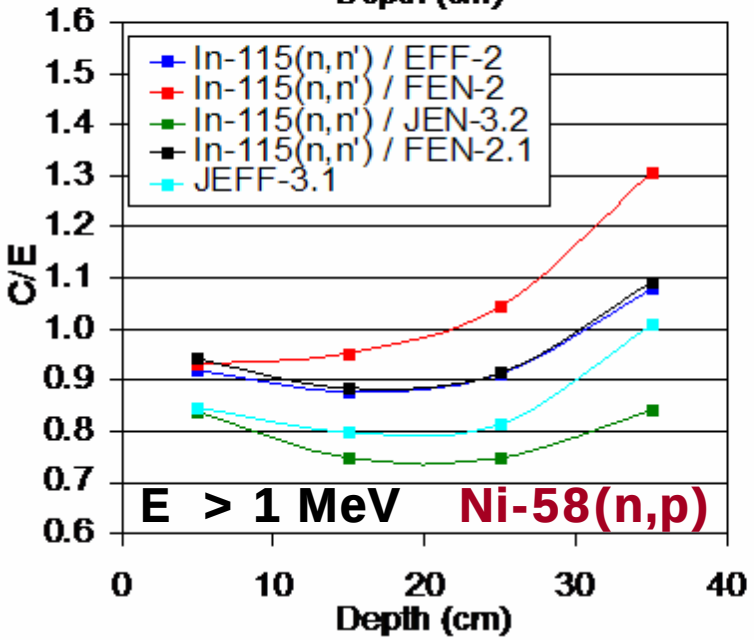


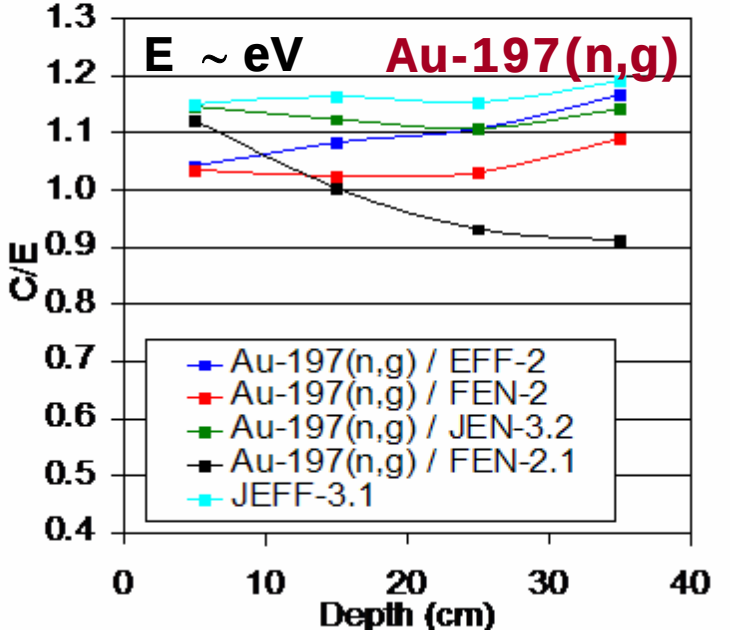
## *Validation of FENDL-2.1 & JEFF-3.1*

## *Tungsten Experiment*

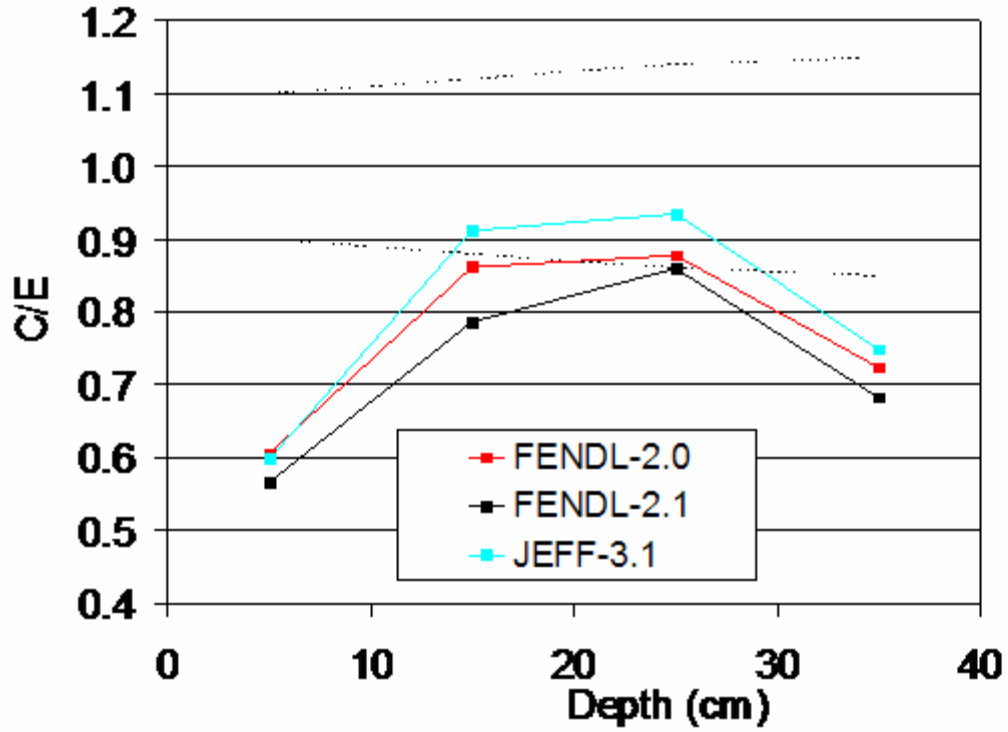


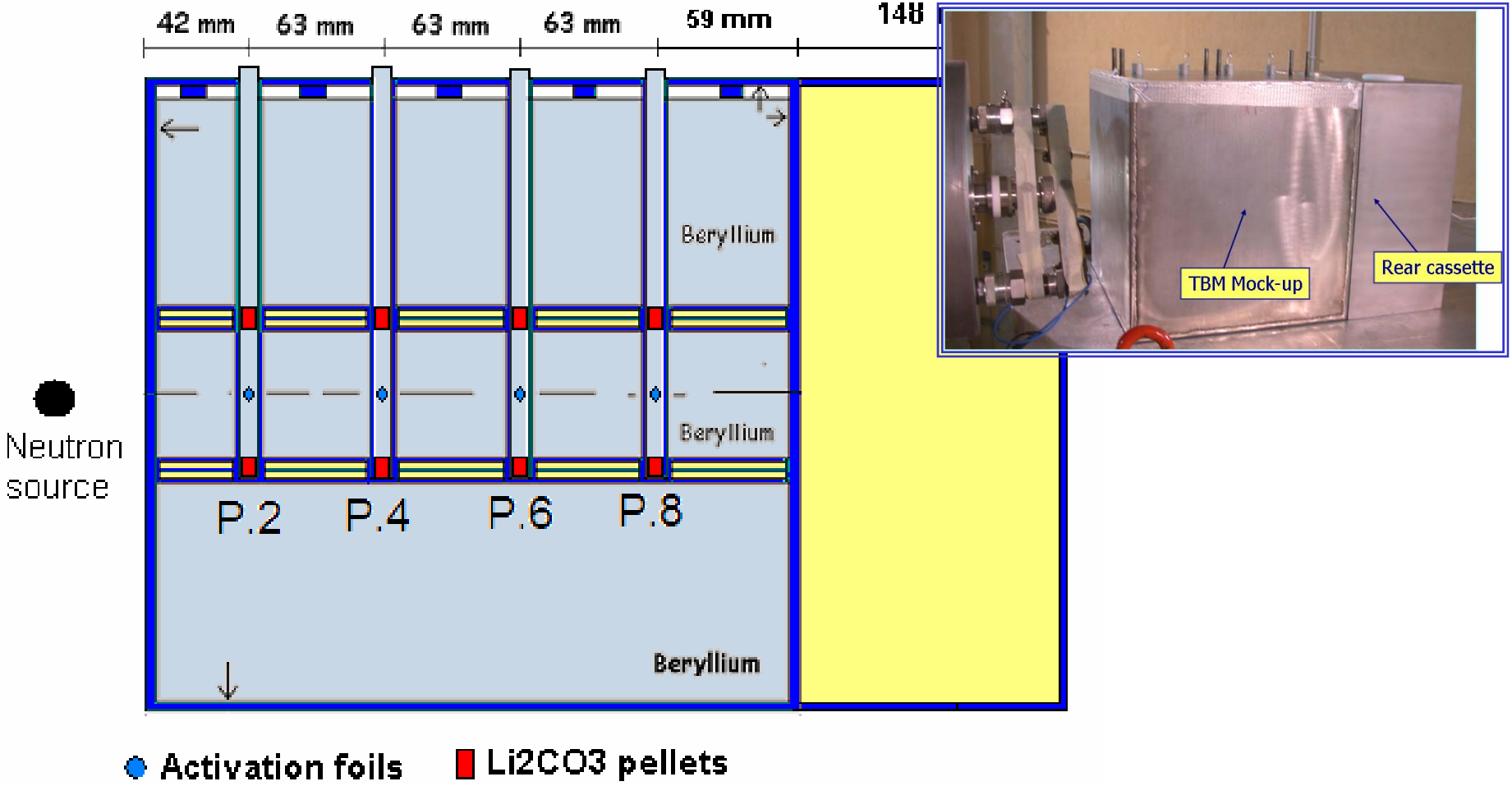



# *Tungsten Experiment*



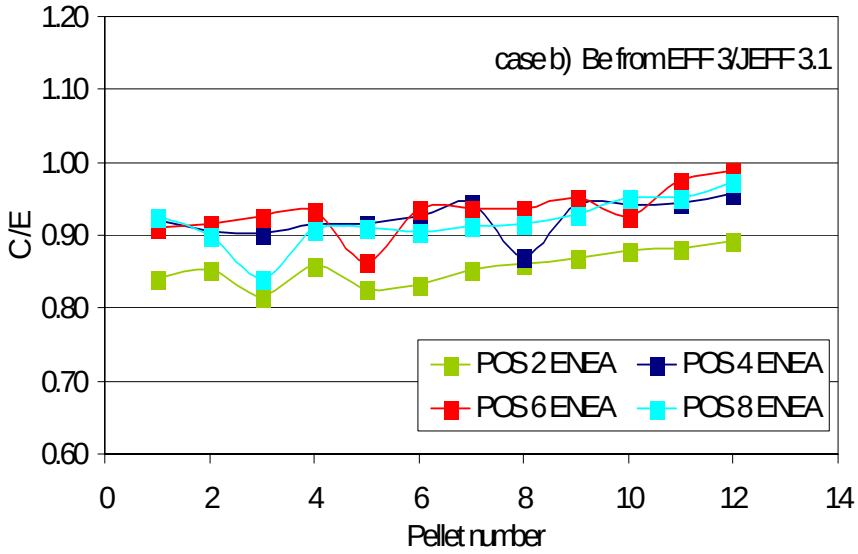

**Gamma Heating in tungsten**

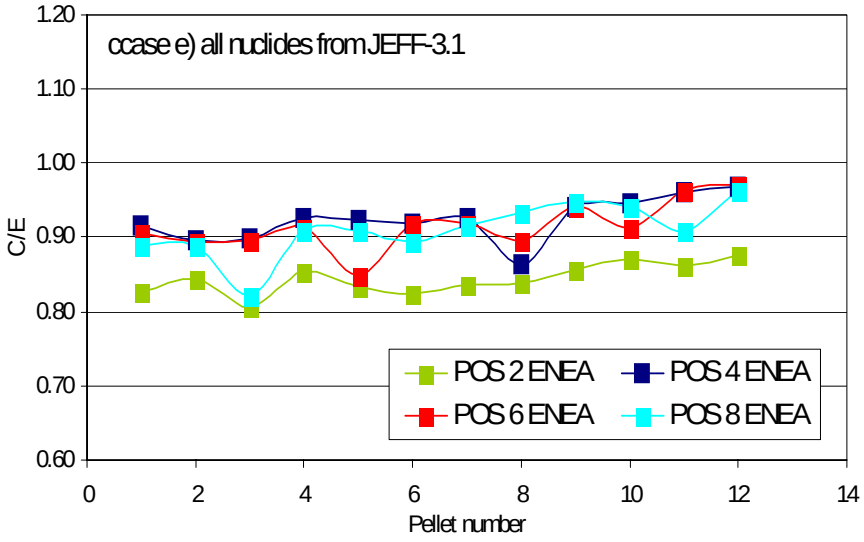
## Mock-up of the EU breeder blanket Helium Cooled Pebble Bed (HCPB)

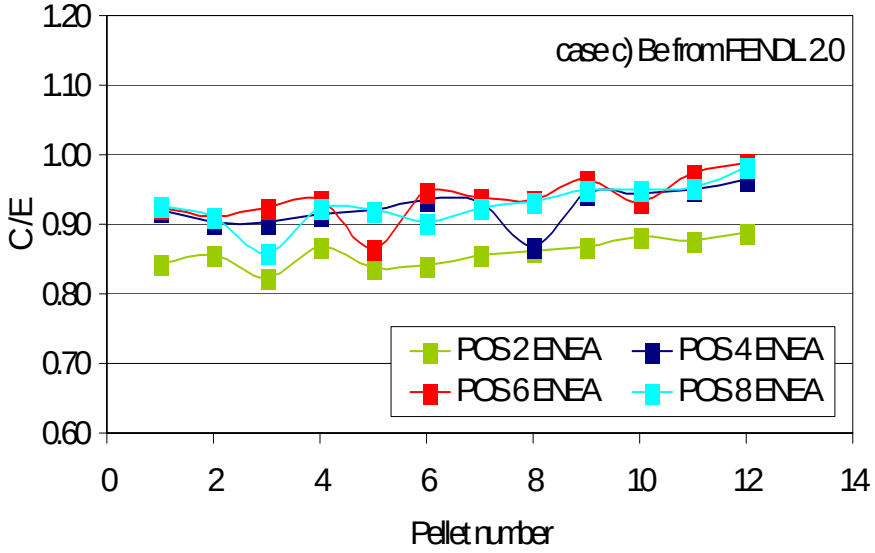


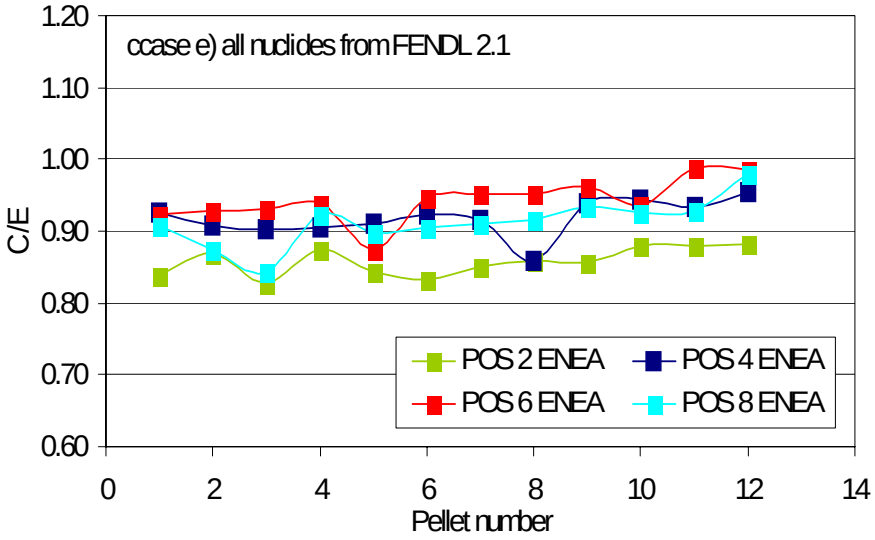

Measurements of tritium production in 4 positions P.2 – P.8 by $Li_2CO_3$ pellets (nat. Li)(12 pellet/position) and of the neutron flux in the central Be layer by activation foils

# Analysis of tritium production in $Li_2CO_3$ pellets

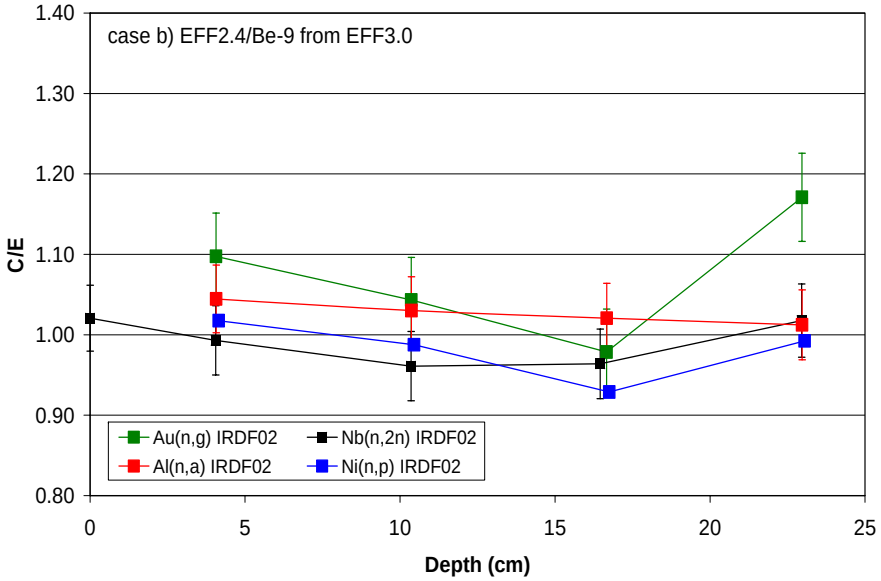


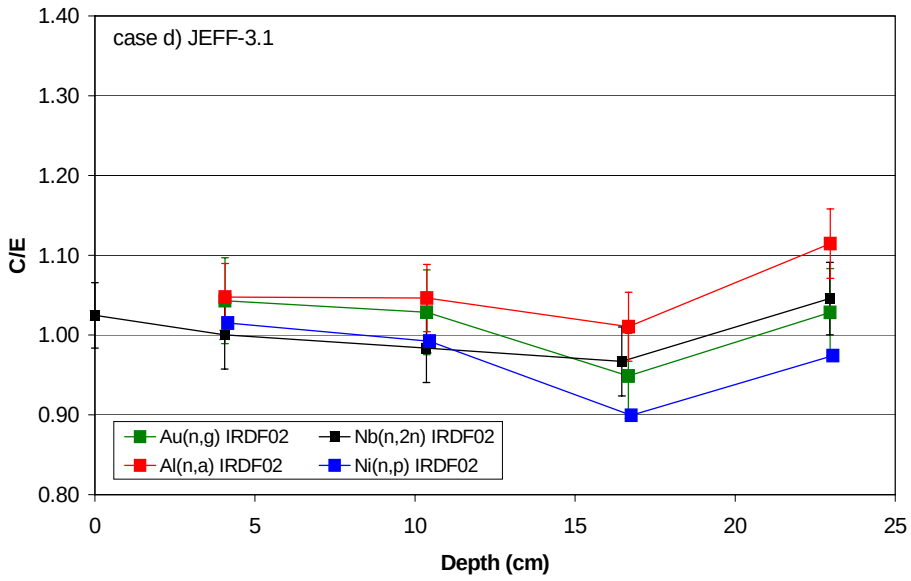



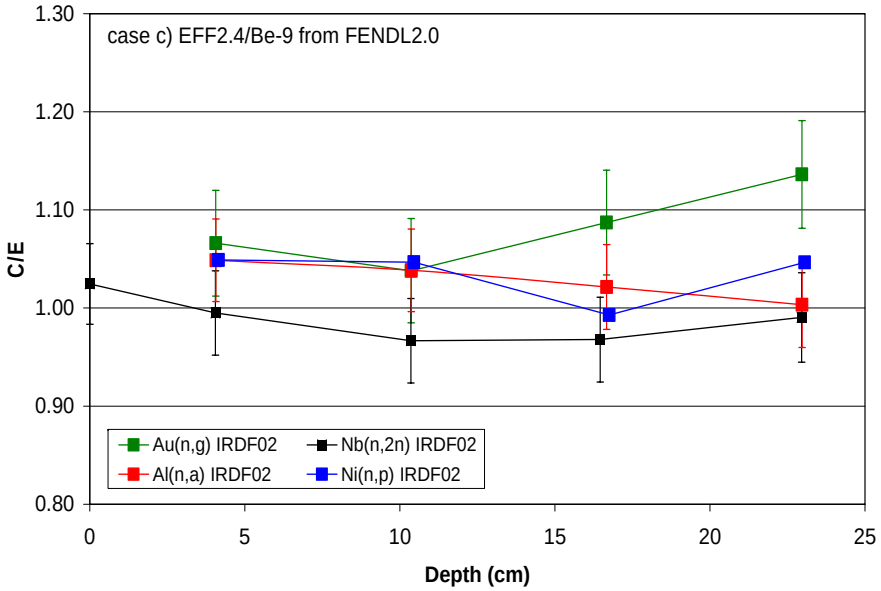



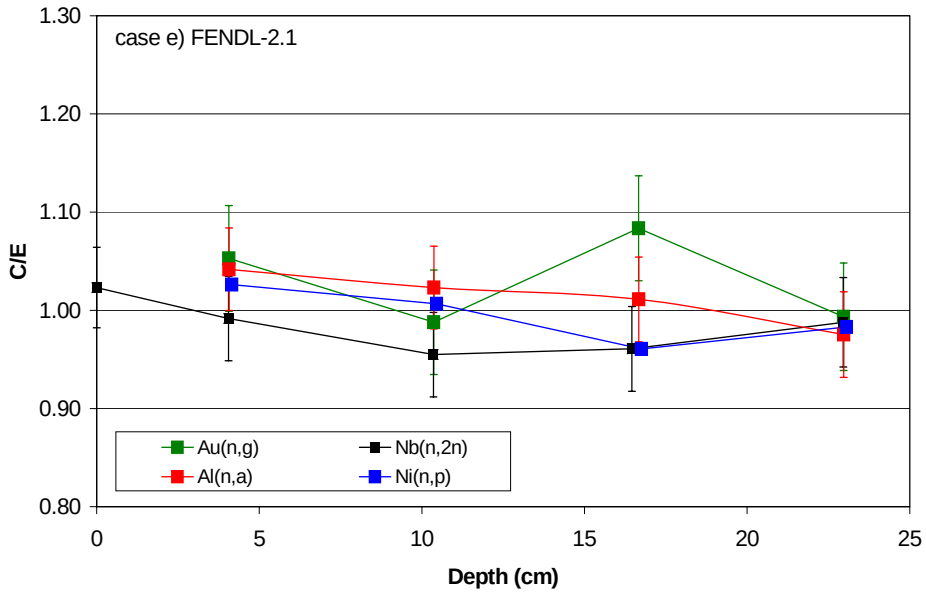



# Analysis of activation measurements



## Conclusions on FENDL-2.1 validation

- All libraries give the same predictions for steel/water assemblies

  Underestimation of fast neutron flux

  Improvement in the nuclear heating calculation

  ➔ convergence for steel

- Significant underestimation of the fast neutron flux is found in SiC block with FENDL-2.1~2.0, better results with EFF-3/JEFF3.1

- Significant improvement of the calculation pf fast neutron flux from FENDL-2.0 to FENDL-2.1 in tungsten block, better results with EFF-3/JEFF3.1. Underestimation of gamma heating both with JEFF and FENDL

- Very good prediction of neutron flux in breeder blanket mock-up (Be/ $Li_2CO_3$) – Tritium production underestimated by 10 -15 %. FENDL-2.1~2.0 ~JEFF-3.1