IRSN
INSTITUT
DE RADIOPROTECTION
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Enhancing nuclear safety

Differential and Integral Data Evaluation: An Application to Criticality Safety

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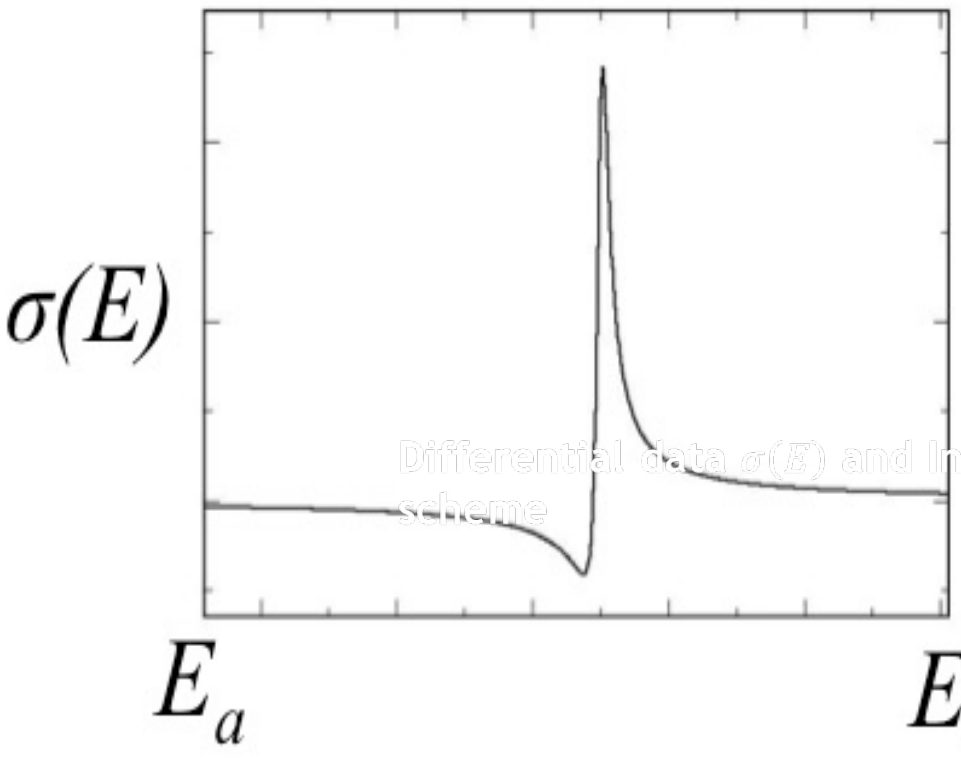
OUTLINE

- Motivation for evaluating titanium
- Differential and Integral Data Evaluation
- ^{48}Ti Resonance Evaluation
- Benchmark Application: VALDUC (France) and SNL(US) experiments
- Concluding Remarks

Motivation

- **Address criticality safety issues of the Actinide Removal Process (ARP) facility at the Savannah River Site;**
- **Monosodium Titanate (MST, $NaHTi_2O_2$) is added to the diluted salt solution to adsorb soluble radionuclides including uranium and plutonium;**
- **Existing ENDF Titanium cross sections and uncertainties used in the ARP criticality calculations were investigated;**
- **Evaluation (including covariance) done with the computer code SAMMY;**

Differential and Integral Data



Differential data $\sigma(E)$ and Integral data R scheme

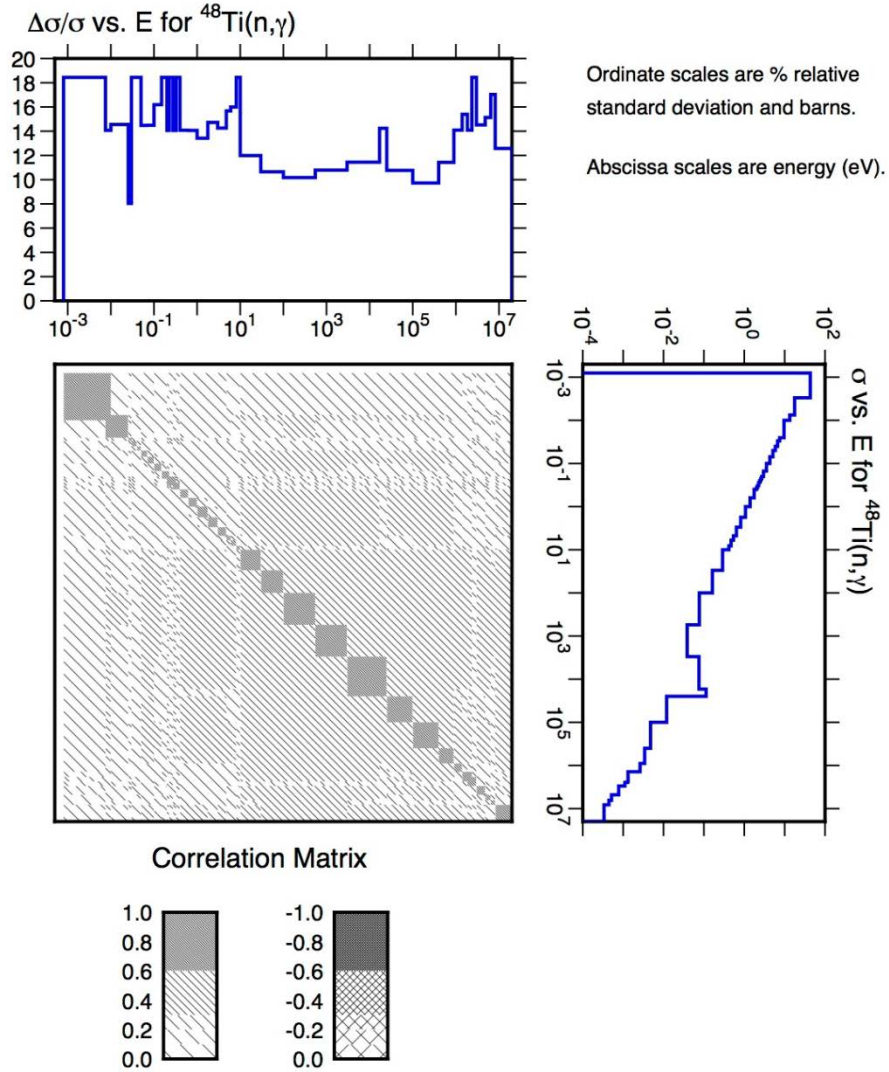
$$R = \int_{E_a}^{E_b} \sigma(E)\,\phi(E)\,dE$$

- Differential data $\sigma(E) \pm \delta\sigma$
- Integral data $R \pm \delta R$

Titanium thermal cross section (Barn Book)

Isotope Name	Abundance (%)	σ_γ (barns) (thermal) 0.0253 eV	$\delta\sigma_{\gamma I}\ \sigma_\gamma$ (%)
^{46}Ti	8.25	0.59 ± 0.18	30.5
^{47}Ti	7.44	1.63 ± 0.04	2.4
^{48}Ti	73.72	8.32 ± 0.16	1.9
^{49}Ti	5.41	1.87 ± 0.04	2.2
^{50}Ti	5.18	0.18 ± 0.03	16.7

Existing ENDF ^{48}Ti Uncertainty



- Capture cross section uncertainty ~12 to 18 %
- According to the Barn Book the thermal capture cross section uncertainty ~2 %

^{48}Ti Resonance Evaluation

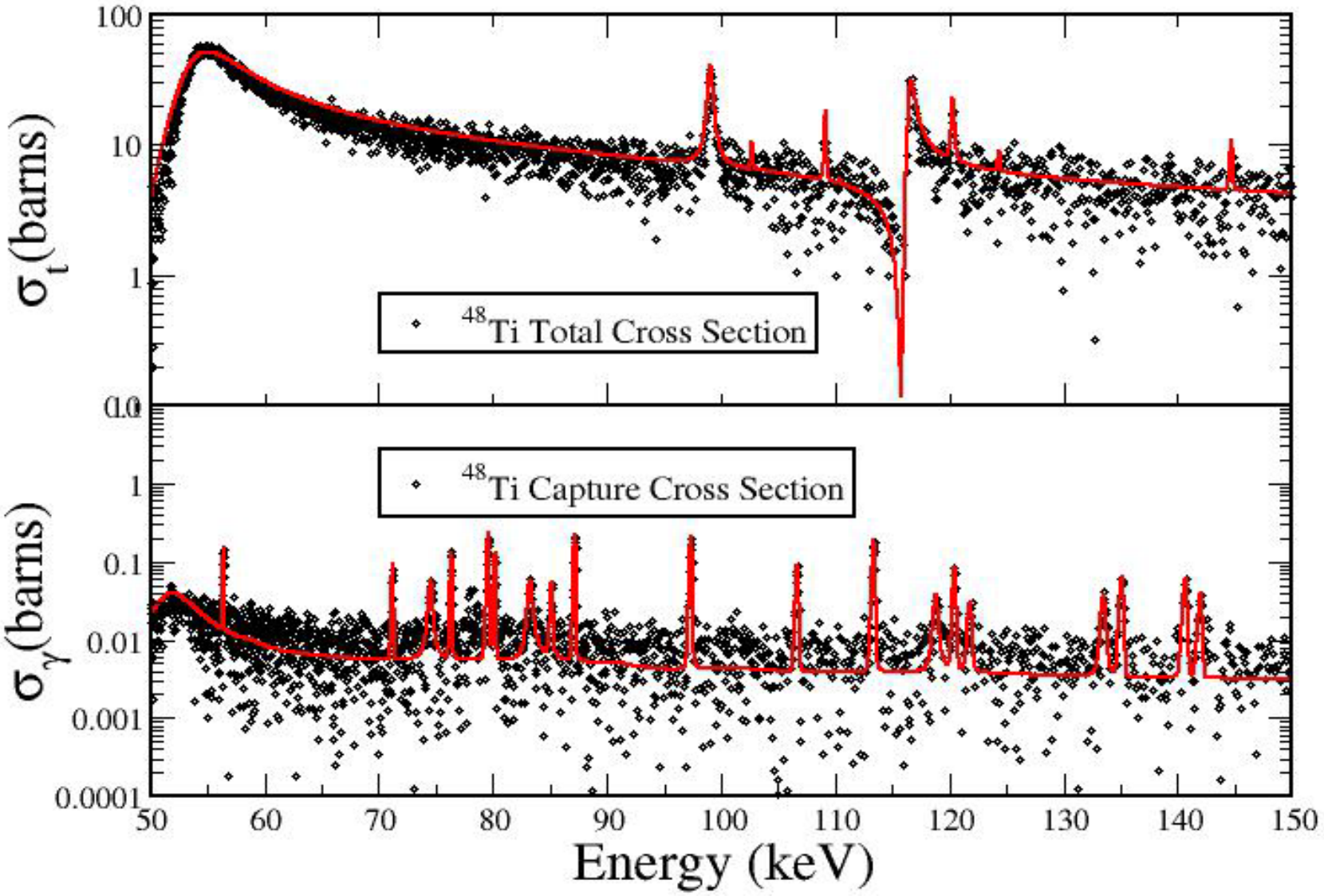
- Evaluation tool: SAMMY
- Energy range: Thermal to 400 KeV
- Experimental Data Base: transmission (total cross section), capture cross section*
- Resonance Formalism: R-Matrix (Reich-Moore)
- Final Results: Resonance Parameters (RP) and Resonance Parameter Covariance (RPCM)

***Limited capture cross section measurements available**

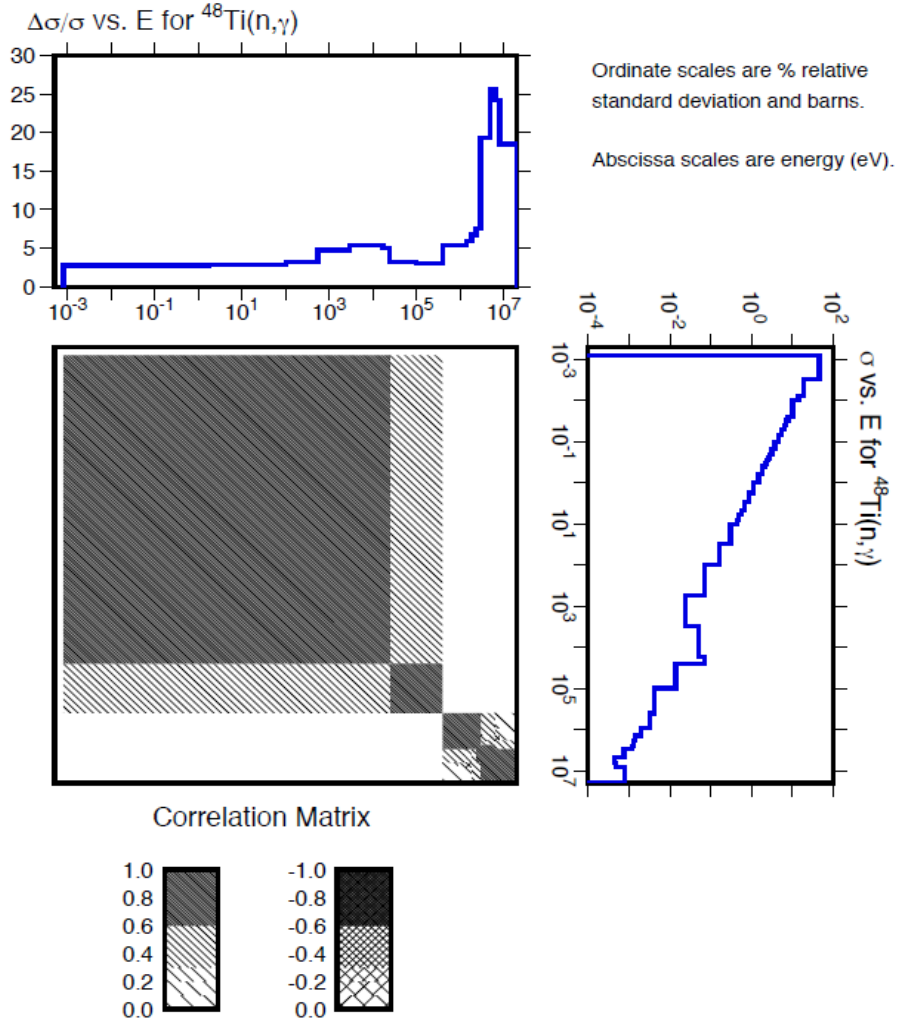
Experimental Data Base (measurements done at ORELA)

Data Set	Energy Range (keV)	Flight Path (meters)	Thickness (at/b)
Natural Titanium			
Transmission (σ_t)	0.01 – 500.0	79.827	0.052966
Transmission (σ_t)	0.01 – 500.0	79.827	0.008785
Capture (σ_γ)	0.01 – 500.0	40.116	0.035158
Enriched ^{48}Ti (99.32 %)			
Transmission (σ_t)	0.01 – 500.0	79.827	0.028185
Transmission (σ_t)	0.01 – 500.0	79.827	0.0011821
Capture (σ_γ)	0.01 – 500.0	40.116	0.0091386

Fitting of the total and capture cross sections



Uncertainty and correlation for the capture cross section



- **New evaluation leads to a capture cross section uncertainty of ~2.8 % at thermal**

Cross section at thermal (0.0253 eV) and capture resonance integral

Quantity	ENDF/B-VII.0	New ^{48}Ti Evaluation ENDF/B-VIII.0
σ_γ	7.84	8.32 ± 0.23* (~2.8 %)
σ_s	4.36	4.04 ± 0.20
σ_t	12.20	12.35 ± 0.30
I_γ	3.68	3.78 ± 0.17

*Uncertainty derived from the data evaluation

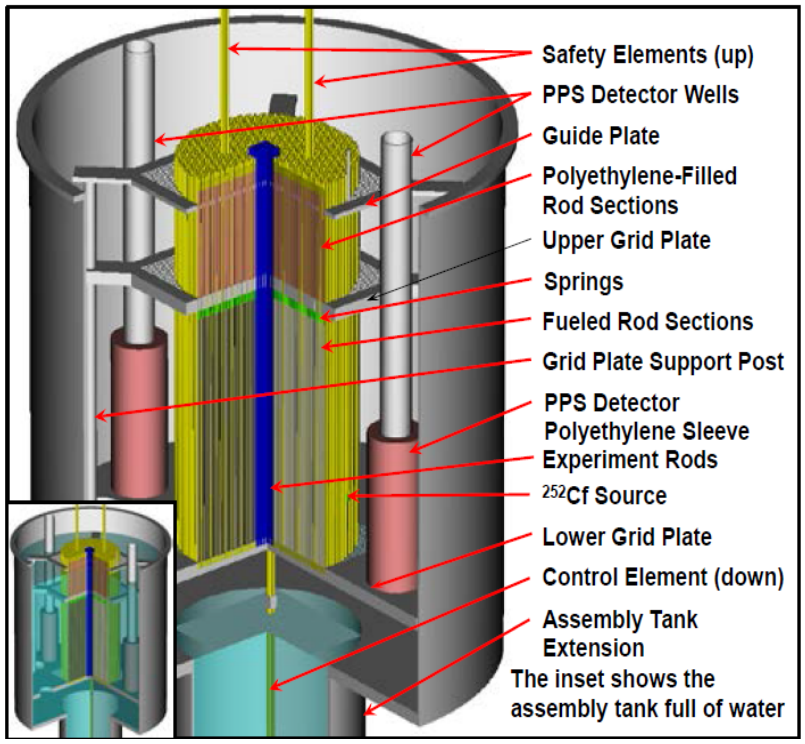
Test of the evaluation on benchmark calculations

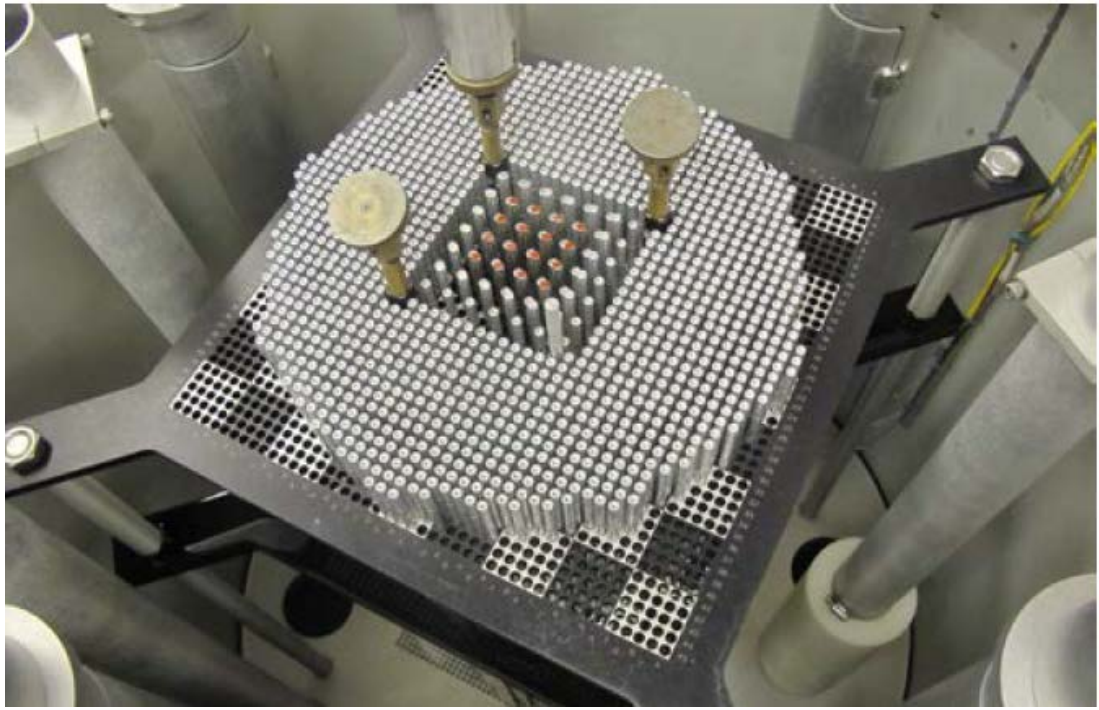
- Nine benchmark experiments taken in the US (SNL)

- Four experiments carried out in France (Valduc)

Integral Benchmark Experiments

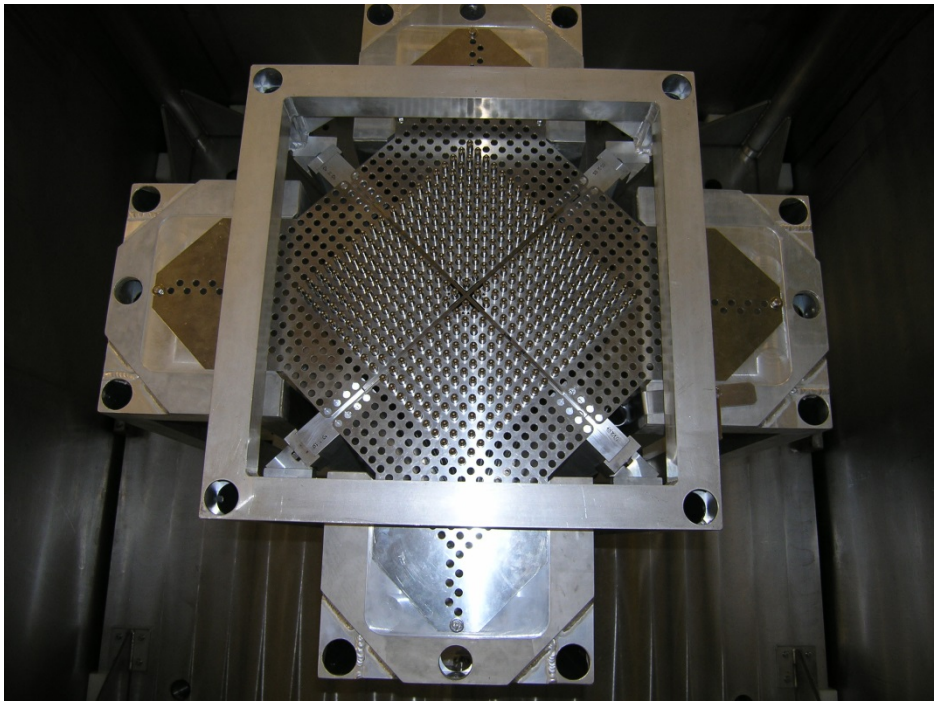
- **Experiments in the US: Nine benchmark experiments Performed at SNL on the SPRF/CX facility.**
- **Experiments included in the ICSBEP handbook: LEU-COMP-THERM-097**

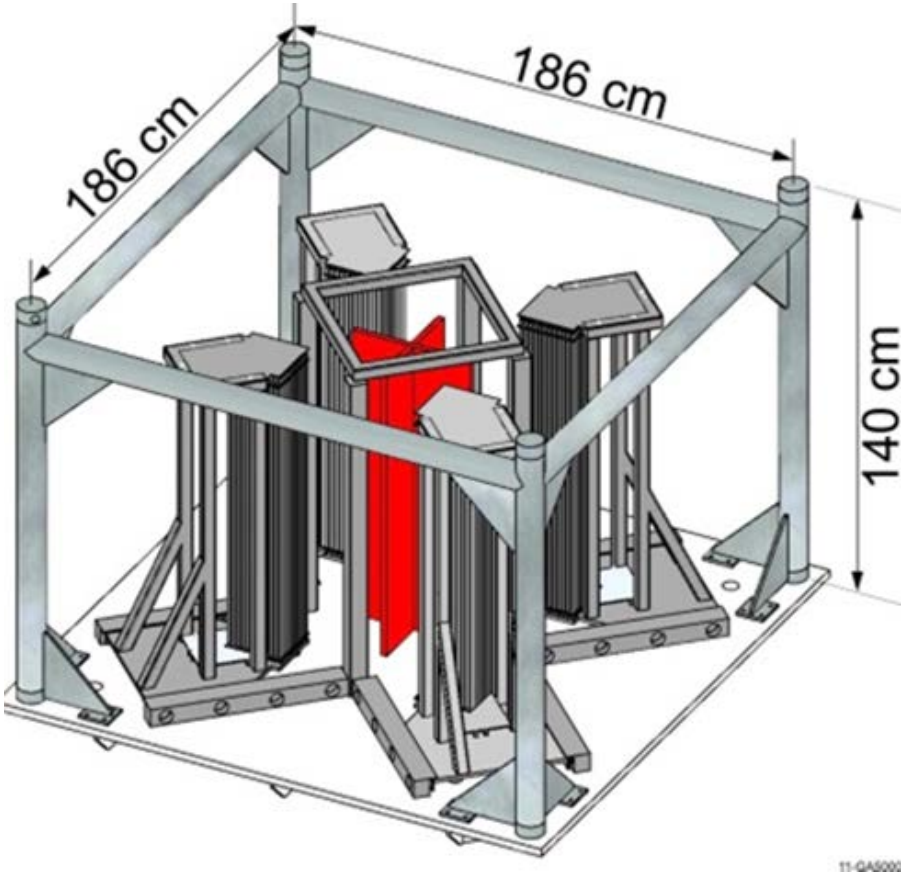




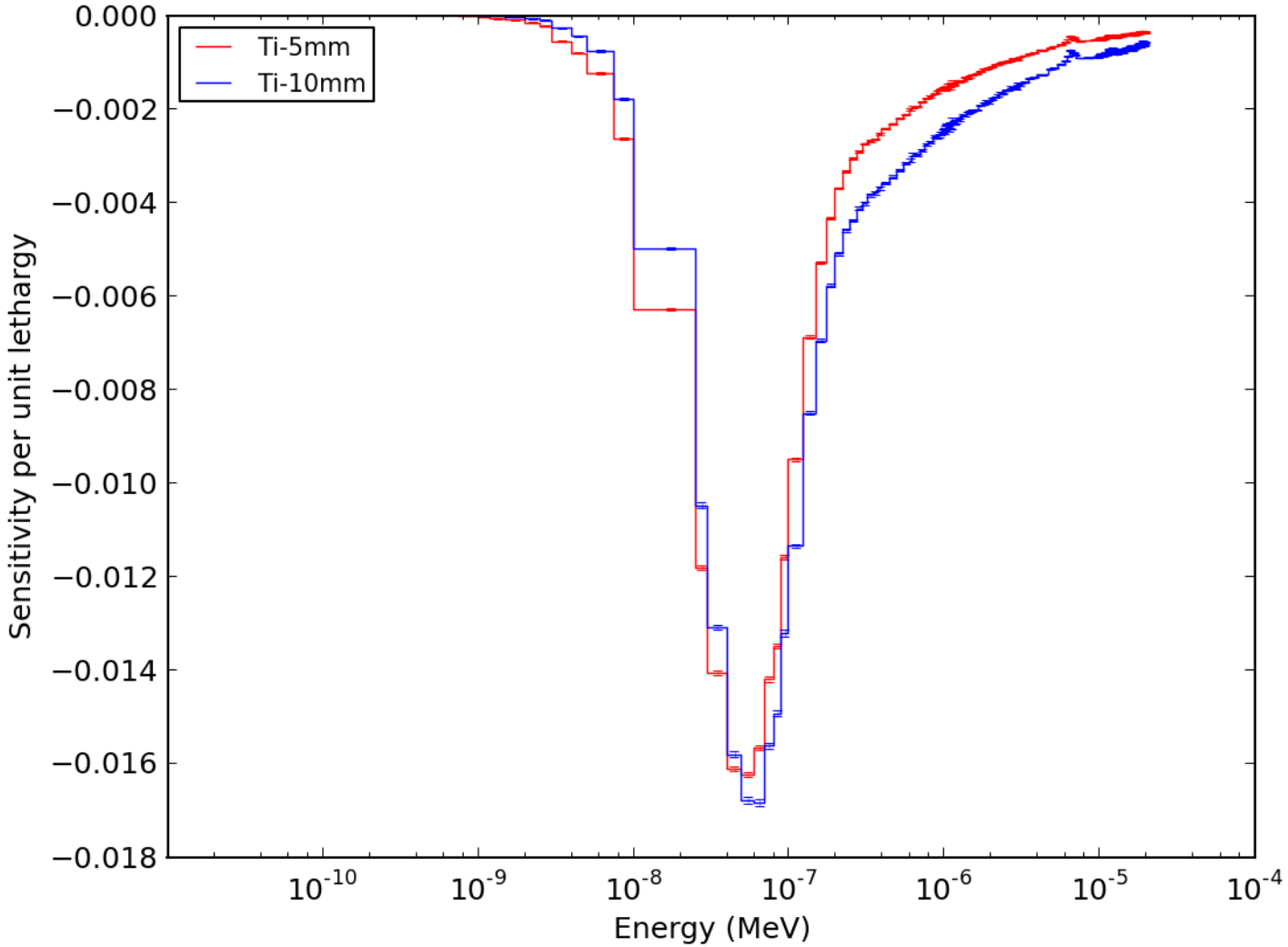
Integral Benchmark Experiments

- Experiments in France: Four experiments carried out at CEA/Valduc Apparatus B under the MIRTE program.
- Experiments included in the ICSBEP handbook: LEU-COMP-THERM-074

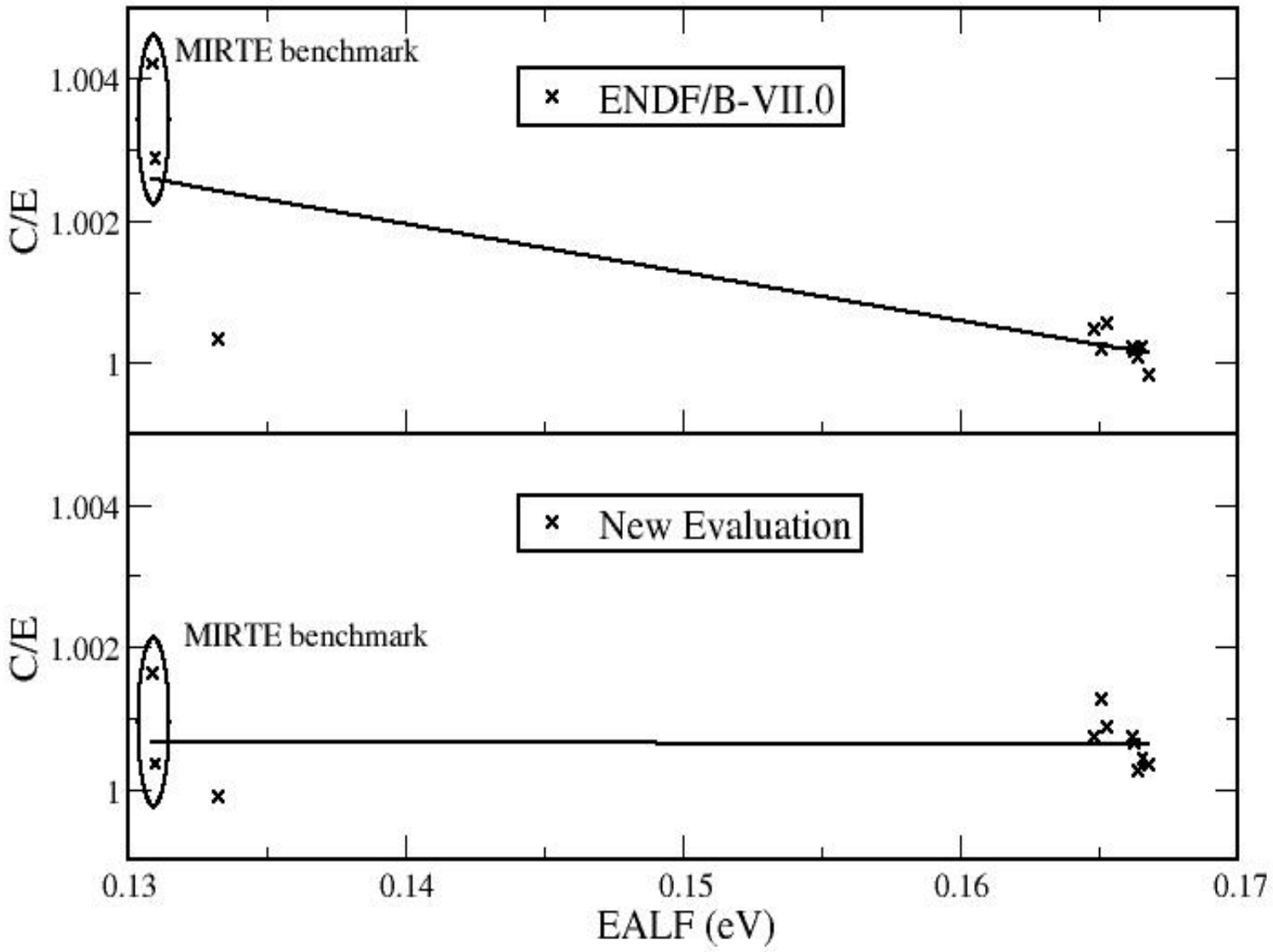




k_{eff} sensitivity to the capture cross section of ^{48}Ti for two MIRTE benchmark experiments



C/E Results for the Revised ^{48}Ti evaluation



Concluding Remarks

- Issues with titanium evaluation for criticality safety addressed;
- Evaluation of differential data carried out using the R-matrix formalism;
- Covariance based on experimental data generated. Revised ^{48}Ti covariance leads to smaller uncertainty in the k_{eff};
- Benchmark testing using criticality benchmark experiments from Valduc (France) and SNL (US) indicate that differential data and evaluation improved integral results;
- The results demonstrate the importance of differential and data for nuclear data validation;

FLOW DIAGRAM

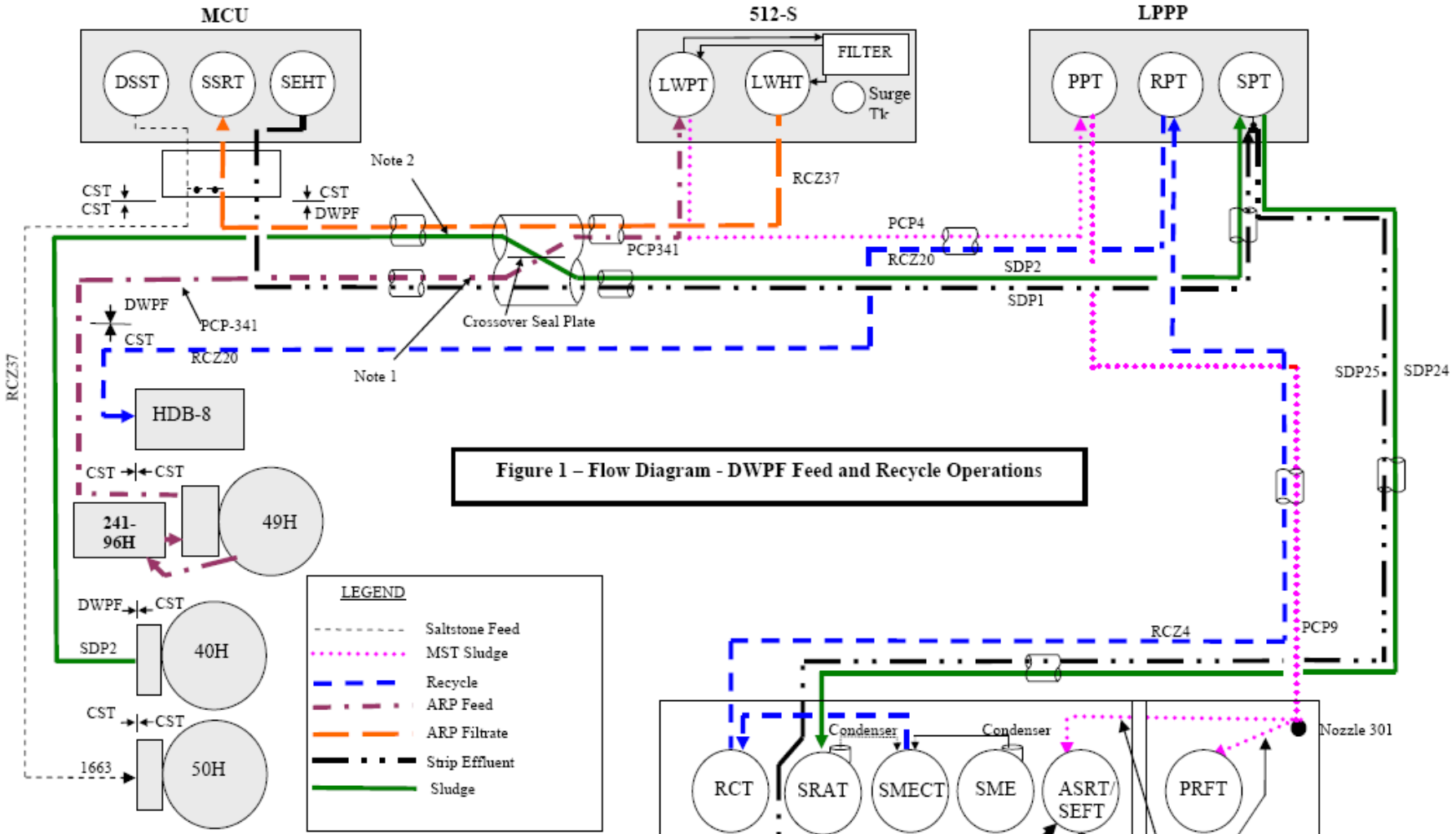


Figure 1 – Flow Diagram - DWPF Feed and Recycle Operations

(1) ARP Feed Line PCP341 Jacket from Tk 49 to the crossover sealplate drains thru SDP2 Jacket to "D" (LDB 20) or thru SPD1 Jacket to "C" (LDB 20).
(2) Sludge Line SDP2 Jacket from Tk 40 to the crossover sealplate drains thru PCP341 Jacket to "K" (LDB 70) or RCZ37 – Lower core to "J" (LDB 190).
(3) For ARP/Sludge Operation, the MST/Sludge may go to the ASRT or the PRFT (only one will be jumpered at a time). For ARP & MCU Operation the flow will go to the PRFT.