Nuclear Data Testing at AECL

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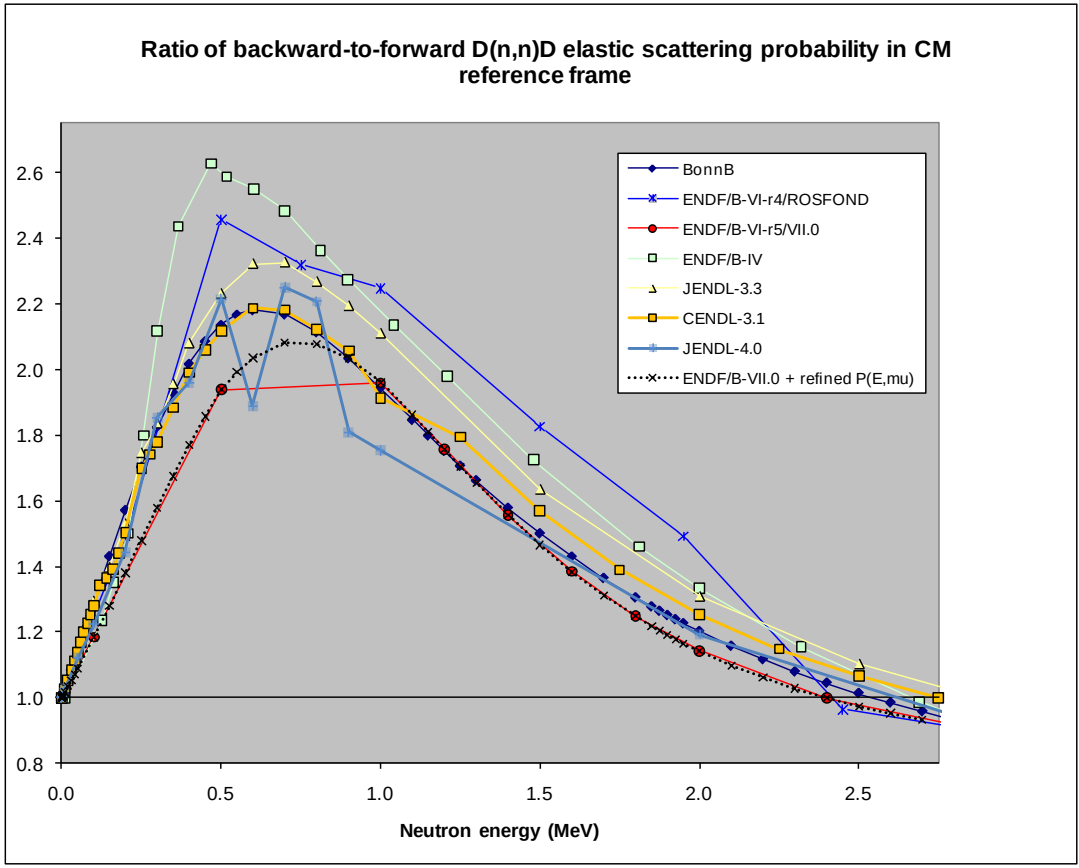
AECL EACL

Outline

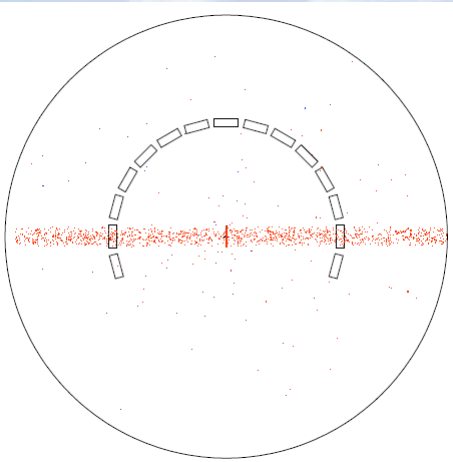
- Deuterium
- Oxygen
- WR-1 WRAP-UP Project
  - Possible Zr & other data for International Reactor Physics Experiment Evaluation Project (IRPhEP)

Comparison of D(n,n)D P(E,μ) anisotropy in different nuclear data libraries

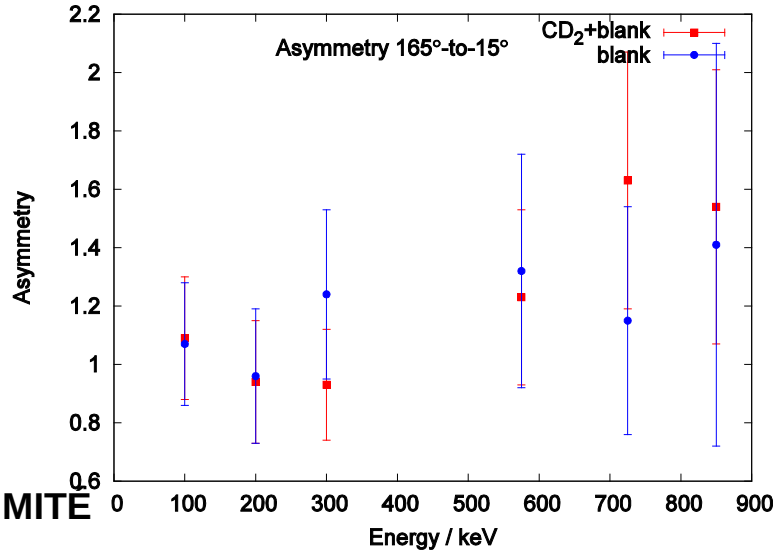
- Compare ratio of cumulative **backward-to-forward scattering probability** with energy <2.5 MeV
  - U.S. **ENDF/B-IV** (1967) & **VII.0** (2006)
  - Russian **ROSFOND** (2007) [**ENDF/B-VI.4**]
  - Chinese **CENDL-3.1** (2009)
  - Japanese **JENDL-3.3** & **4.0** (2010)
  - **BonnB** ***(J. Svenne & L. Canton)***
- ENDF/B-VII.0 is ***numerically inadequate*** in the range from 0.5 to 1 MeV; piecewise cubic polynomial interpolation increases calculated *k* by **~0.8 mk** (80 pcm) for HST-04

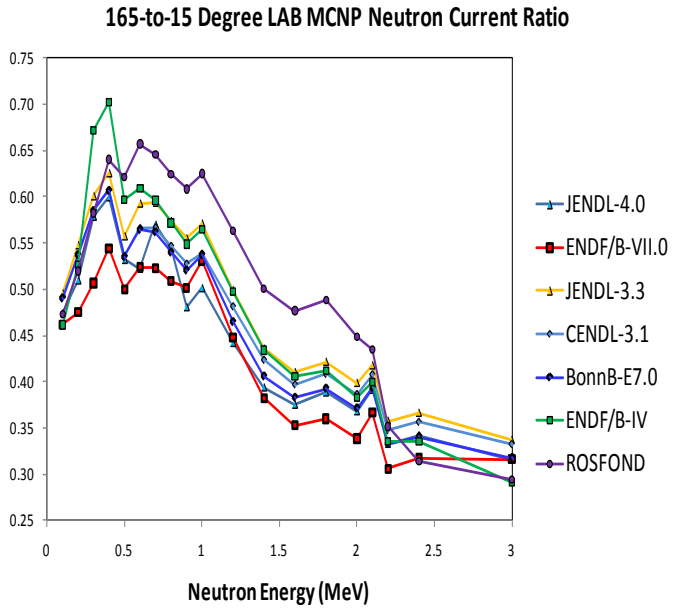


CD_2 simulation & preliminary GELINA results

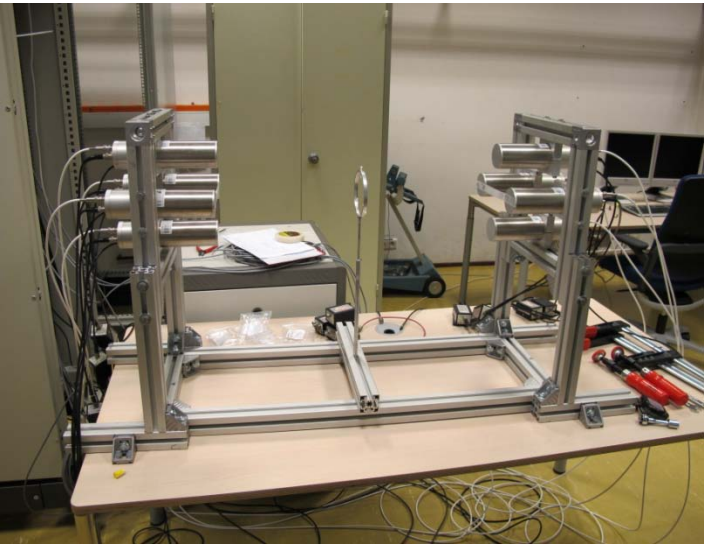


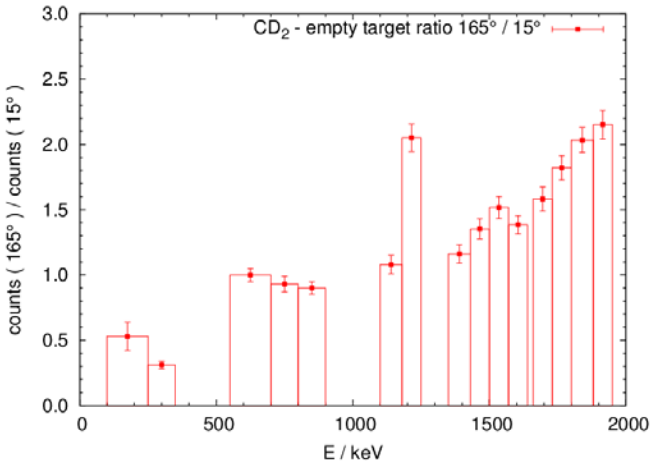
- Simplified MCNP simulations (2010) using 'virtual' detectors indicate good sensitivity to D nuclear data
  - Maximum deviations of **36%** (1.8 MeV) & **>22%** from 0.3 to 2.0 MeV
  - ***But***, disagree with preliminary measurement results; more realism needed
- Large experimental uncertainties due to low neutron count rates at 300 m from GELINA source; WINS-2010
  - Setup transferred to nELBE accelerator in **Dresden**
  - new measurements taken in 2011

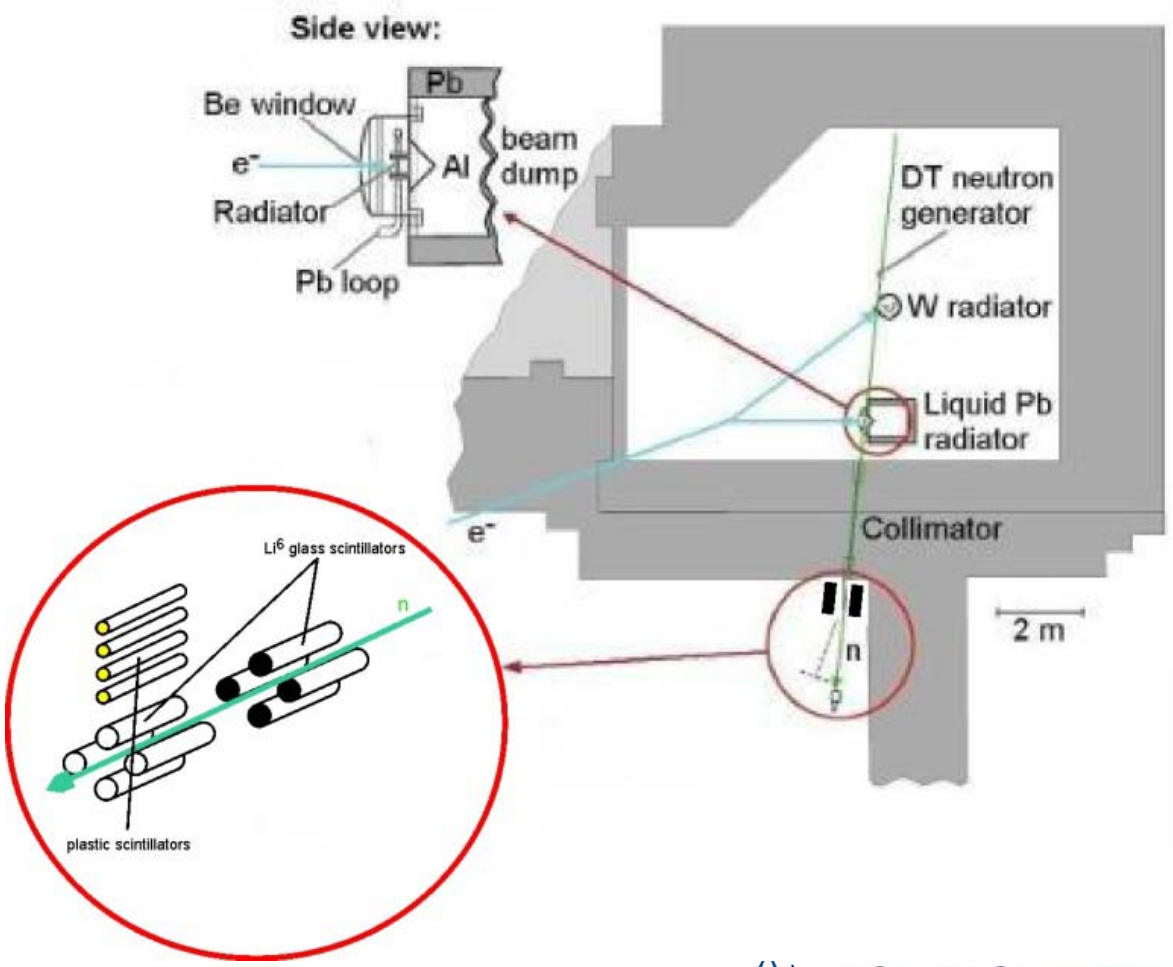




- 1 week of CD_2 data collection; much improved statistics

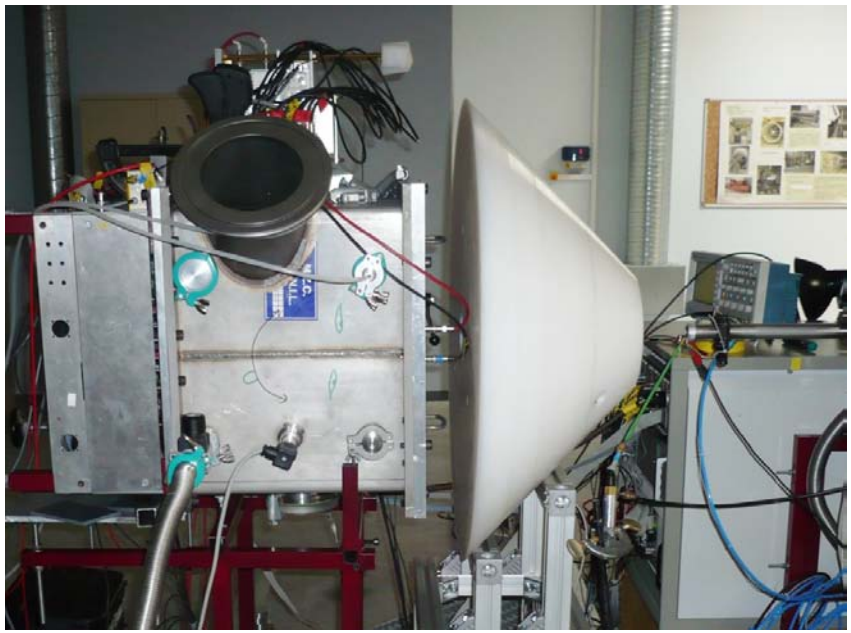


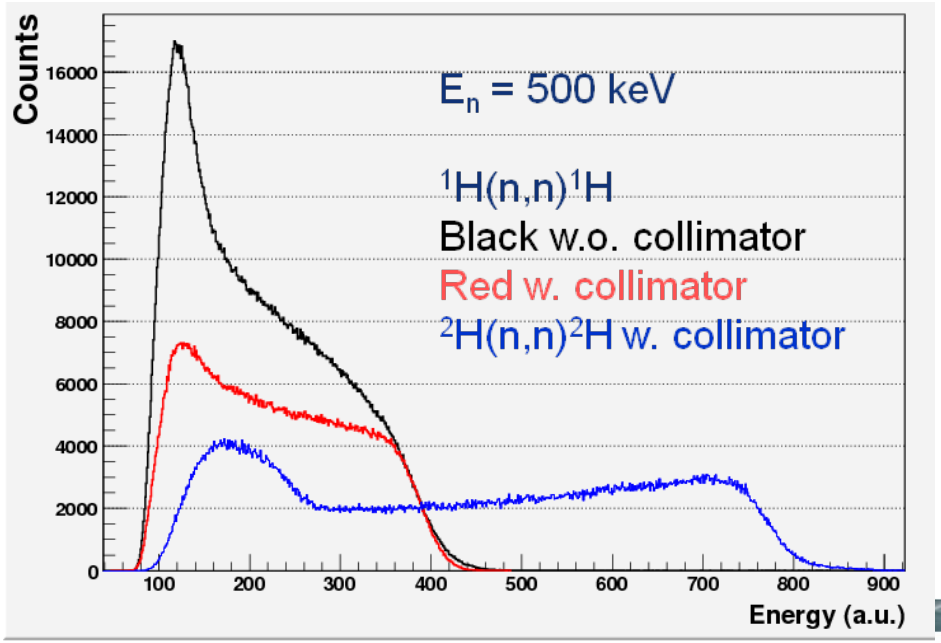




Deuterium recoil measurements

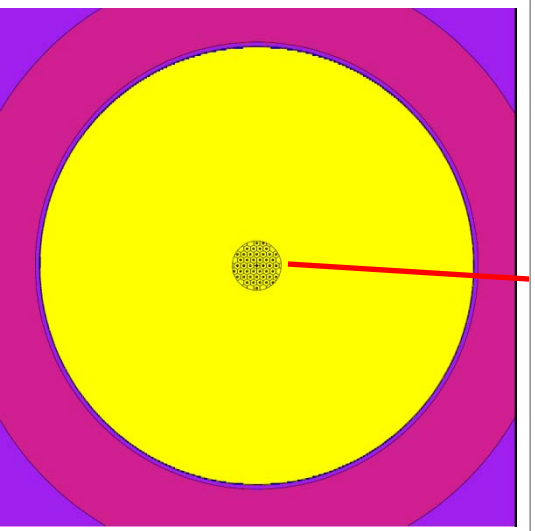
- **CENBG Bordeaux** (CNRS/IN2P3) - EFNUDAT funded experiment, Li(p,n) neutrons from AIFIRA VdG/Pelletron; **Time Projection Chamber (TPC)**
- CNRS involvement: Bertram Blank, Pauline Ascher, Charles Eduard Demonchy, Teresa Kurtukian-Nieto, Beatriz Jurado, Mourad Aïche, Antoine Bacquais, Jerome Giovinazzo, Mathias Gerbaux, Ludovic Mathieu, Laurent Audirac, Guillaume Boutoux, Nassima Adimi, Jerome Souin, Gregory Canchel, Laurent Serani, Philippe Alfaurt, Serge Czajkowski, Iulia Companis,Nicollas Capellan, Gerard Barreau
- **2010 June** data taken at three energies (**300, 500, 700 keV**), 2 orientations; **deuterated P10 = Ar90(CD4)10 gas**; measured amplitude spectra & recoil track orientations
- ***But, may not produce useable results due to analytical difficulties & wall effects***

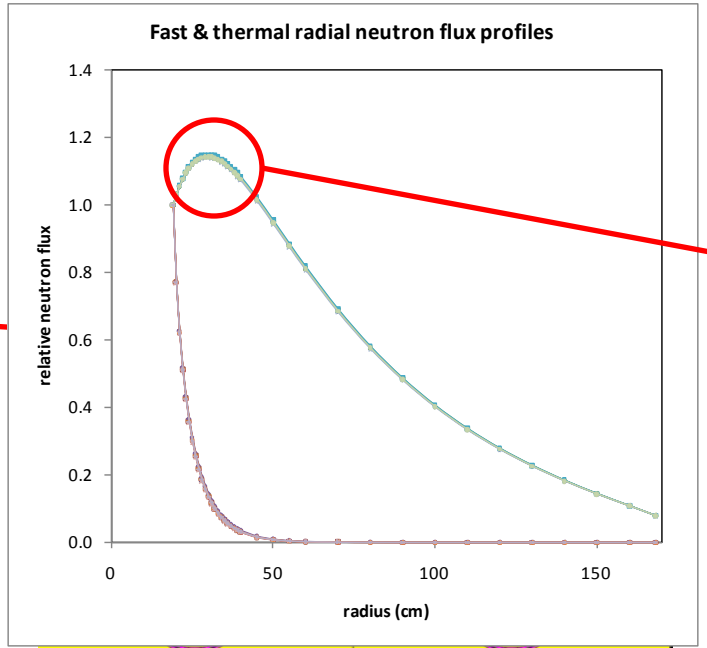


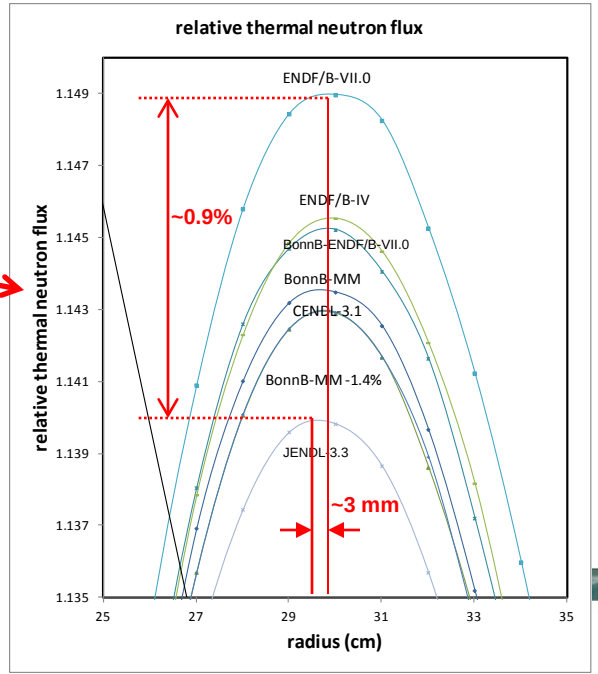


Potential new HEU experiments in ZED-2

- Basic idea is to increase the reactivity sensitivity to the D data by ***mimic***king the 1950s ***LANL HST experiments***
- NRU-type HEU Moly-99 target rods were tested in fuel substitution experiments in early 1980s; data being re-analyzed with MCNP
- Simulations of hypothetical compact lattice based on MAPLE-type HEU target fuel elements
  - Good reactivity sensitivity: **~9 mk** CENDL-3.1/ENDF/B-IV
  - **~0.9%** difference in reflector thermal flux peak; **3 mm** difference in radius of peak

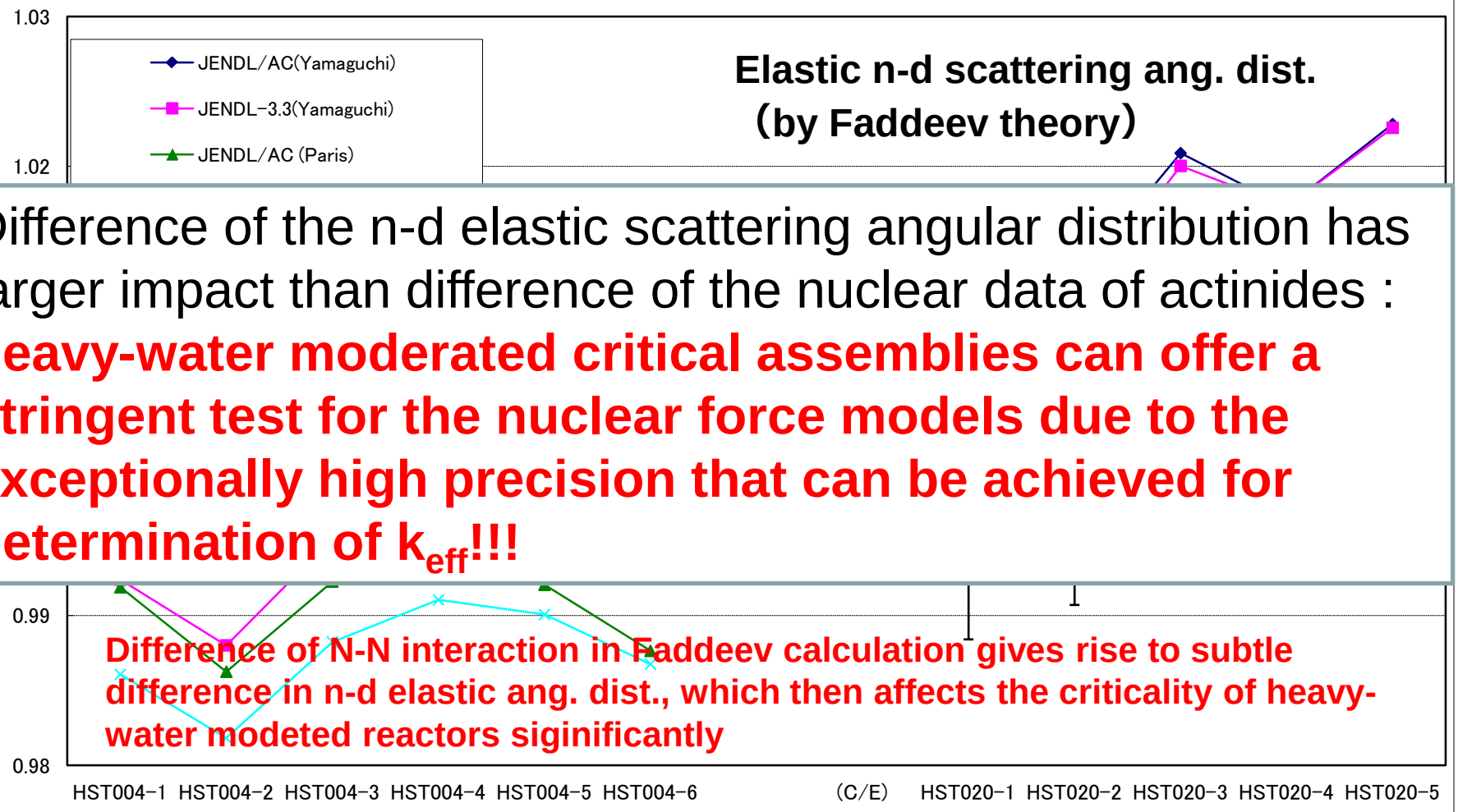






[independent confirmation: Satoshi Chiba, JAEA, 2011 Nov. 3]

Criticality of heavy-water moderated reactors (k_{eff})



Difference of the n-d elastic scattering angular distribution has larger impact than difference of the nuclear data of actinides : **heavy-water moderated critical assemblies can offer a stringent test for the nuclear force models due to the exceptionally high precision that can be achieved for determination of k_{eff}!!!**

heavy-water moderated, heavy-water reflected small reactors

bare heavy-water moderated reactors (middle size)

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ICSBEP : International Criticality Safety Benchmark Evaluation Project

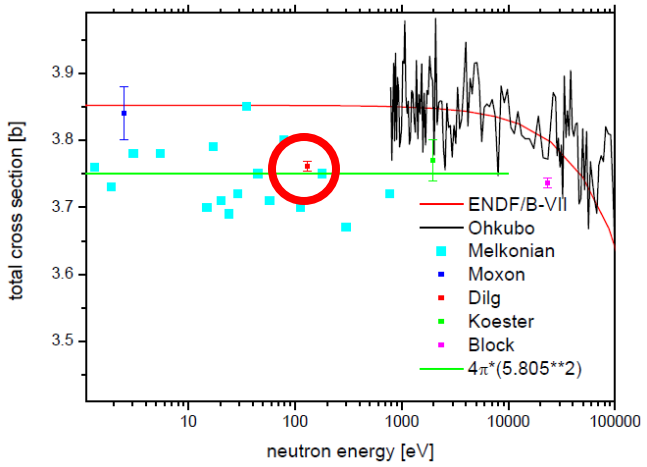
Thermal $\sigma_{tot;s}(^{16}O)$ & $\sigma_{tot;s}$(O-nat)

- We noticed that modern evaluated data library values for ^{16}O (& O-nat.) σ_{tot} & σ_s are ***too high*** compared to best experiments

  (see http://www.nndc.bnl.gov/proceedings/2010csewgusndp/Monday/CSEWG/CSEWG-10-KSK.pdf)

- Observation confirmed in data review by Arjan Plompen & Stefan Kopecky (WINS-2010)
- ENDF/B-VII.0 $^{16}O\sigma_{tot}$(130 eV) = 3.852 b disagrees with ***Dilg et al. (1971) & ATLAS*** value of 3.761 ± 0.007 b by **13σ** (+2.4%)
- ENDF/B-VII.0 ^{16}O coherent scattering length = 5.875 fm differs from Koester's (1991) value of 5.805 ± 0.005 fm by **14σ** (+1.2%)

JRC EUROPEAN COMMISSION — Total cross section O — irmm — 10



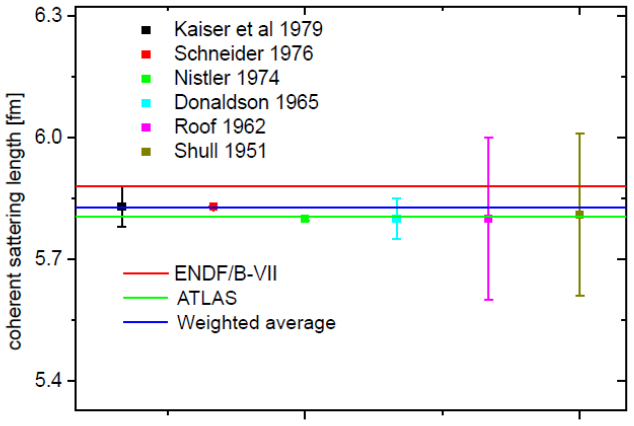
Most accurate cross section measurements use filtered beams to minimize background

These agree with recommended coherent scattering length value of 5.805 fm

They also agree with the weighted average 5.825 fm

But not w. ENDF/B-VII

JRC EUROPEAN COMMISSION — Coherent scattering length ^{16}O — irmm — 9



The weighted average is

5.825(1) fm

The recommended value: ATLAS

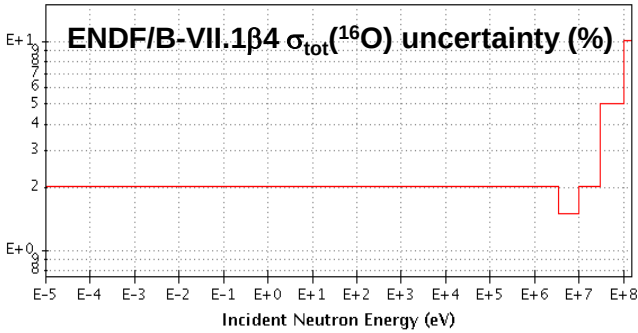
5.805(4) fm

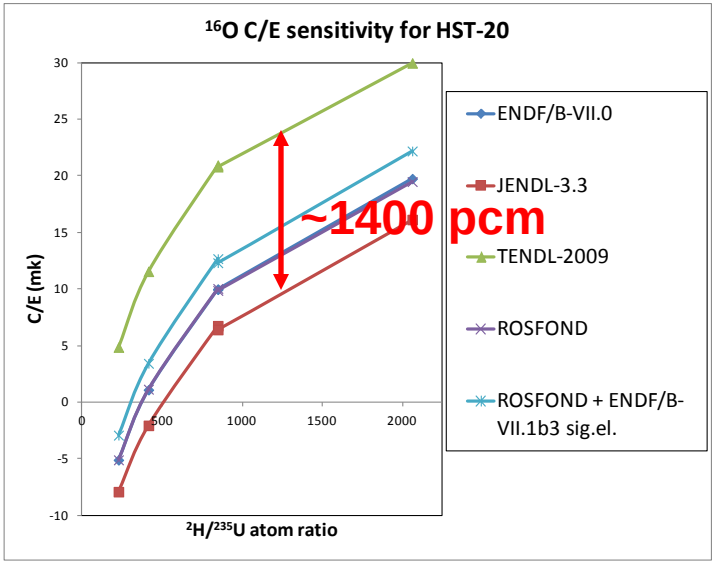
Only outlier: Nistler 1974 Diff: 0.3% level!!!

No basis for the ENDF/B-VII value

Reliability of ^{16}O $\sigma_{tot;\,s}$ &uncertainty data - reactivity impact for HST-20

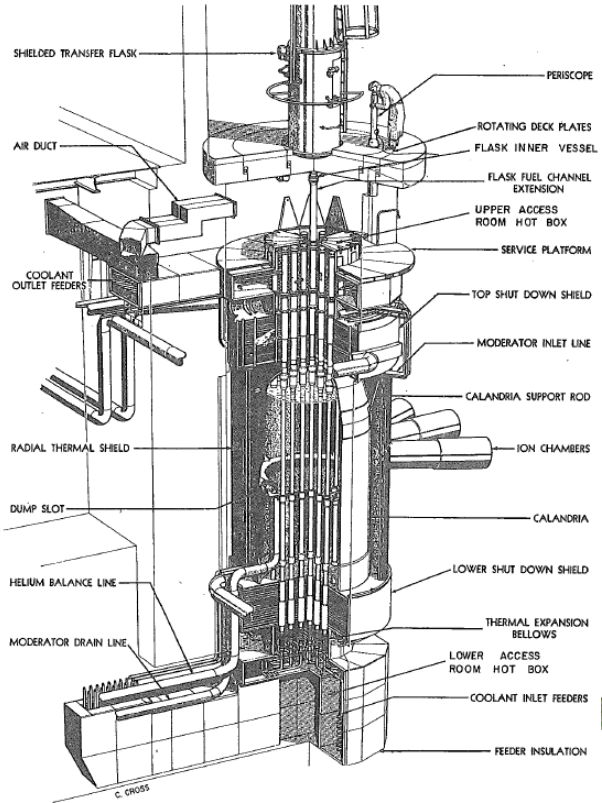
- $\sigma_{tot;\,s}(^{16}O)$ ***uncertainty*** at thermal energy
  - **ENDF/B-VII.1β4**: **±2%** σ_{tot} E<5 MeV; **±1.6%**σ_s E<10 MeV
  - **ROSFOND**: **±3.0%** σ_s E<1 keV
  - **JENDL-4.0**: **±1.0%** σ_{tot} E<1 MeV
  - ***But*, Mughabghab's Atlas (& Dilg 1971)**: $\sigma_{s,th}$ **±0.16%**
- Old (1950's) LANL HEU D_2O Solution Thermal (HST) critical expts.: HST-04 D_2O-reflected spheres; ***HST-20 unreflected cylinders*** show reactivity sensitivity to **^{16}O** nuclear data files
  - Sensitive to: $\sigma_{tot;\,s}(^{16}O, T=0\ K, E\rightarrow 0)$ & low-*E* (&negative-*E*) resonance parameters
  - HST-20 C/E rises with $^{2}H/^{235}U$ atom ratio
  - But, large experimental uncertainty
  - ENDF/B-VII.1β3 ^{16}O $\sigma_{s,\,th}$ seems headed in wrong direction **[β4&5 go back to VII.0]**
- New HEU/D_2O ZED-2 expts. might help clarify





Project WRAP-UP (*Whiteshell Reactor Applied Physics data Utilization & Preservation*)

- **60-MWt** [initially 40 MWt] prototype Organic-Cooled Reactor (**OCR**), WR-1, built by CGE at AECL's Whiteshell Laboratories in Pinawa, Manitoba
- Construction start **1963**; *1st* criticality **1965 Nov. 1 [$14.5 million]**; ceased operation **1985 May**
- Coolant a mixture of terphenyls: Monsanto OS-84 [formerly HB-40] at 315-400°C [<**425°C**], @ **2.28 MPa** inlet; Zr-2.5%Nb-clad **UC** driver fuel
- Very well instrumented for physics: calorimetric power measurements for each channel
- **NEA** interested in getting data into **IRPhEP** database; U.S. & other participation is welcome



Summary of current plans

- nELBE CD_2 scattering MCNP simulations
- Additional measurements by IRMM at nELBE in 2012
- Nuclear theory calculations for ^{2}H & ^{16}O: Juris Svenne & Luciano Canton
- Scoping calculations & plans to support new HEU/D_2O fuel substitution expts. in ZED-2
- Analysis of new ZED-2 Gd measurements in progress
- WRAP-UP Project at AECL-WL to archive reactor physics data of interest to IRPhEP

Postcript

- ZED-2 zero-power critical facility at AECL-CRL is open to collaborative R&D work arrangements & student/staff training; ~200 km/2.5 h NW of Ottawa, Ontario, Canada
- If interested, contact Bhaskar Sur [surb@aecl.ca], Manager – Applied Physics Branch, or contact facility staff [ZED2Facility@aecl.ca]

ZED-2, Chalk River Labs (Circa 1970's)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