Data Testing at AECL

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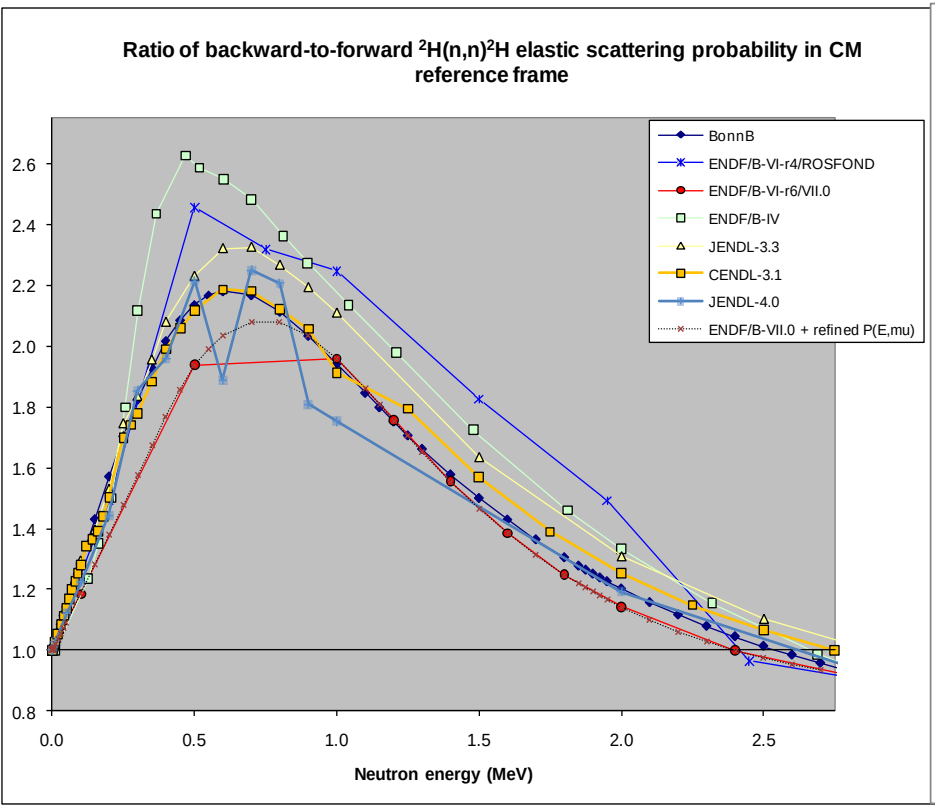
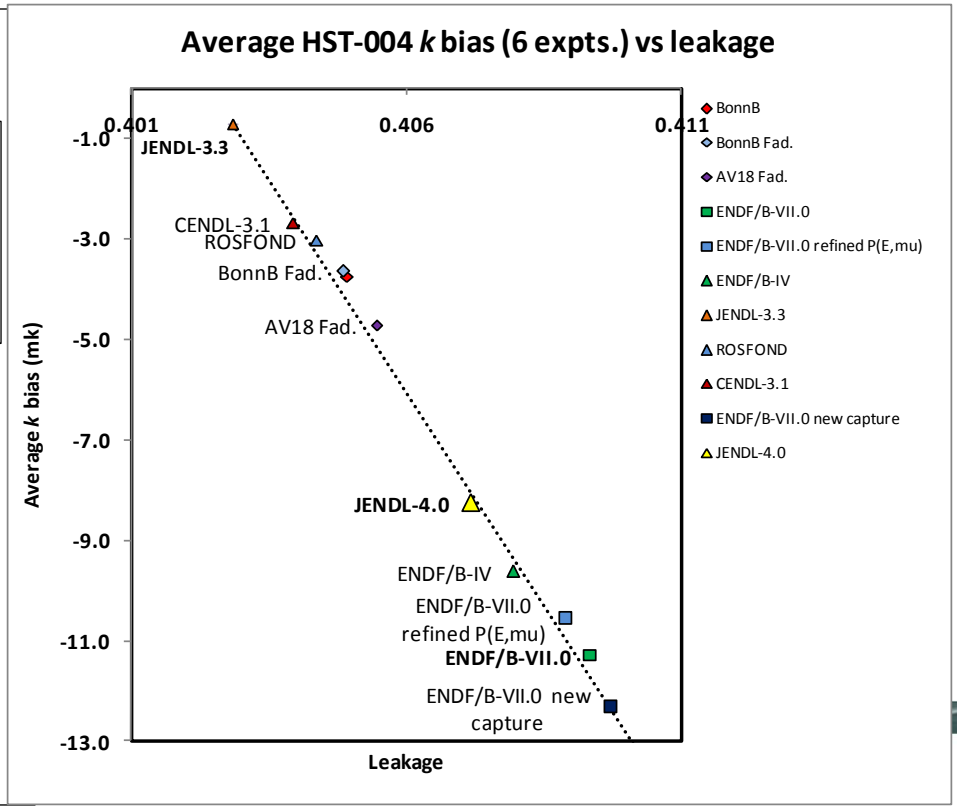
Outline

- Deuterium
  - Angular distributions of elastic scattering
  - Total/scattering cross section at low energy
  - Capture cross section
  - Photonuclear data
  - TSL data
- Carbon/graphite
- Oxygen

Energy-angle distributions P(E,μ) for $^2H(n,n)^2H$ elastic scattering

- Main issue is amount of backscatter <3.2 MeV & reactivity impact this has via neutron leakage from critical systems (up to **~10 mk = 1000 pcm**)
- ENDF/B-VI.5 (& later) P(E,μ) is low relative to ENDF/B-VI.4 (adopted by ROSFOND)
- CENDL-3.1 nuclear-theory close to BonnB results of Canton & Svenne
- New JENDL-4.0 shows some irregularities

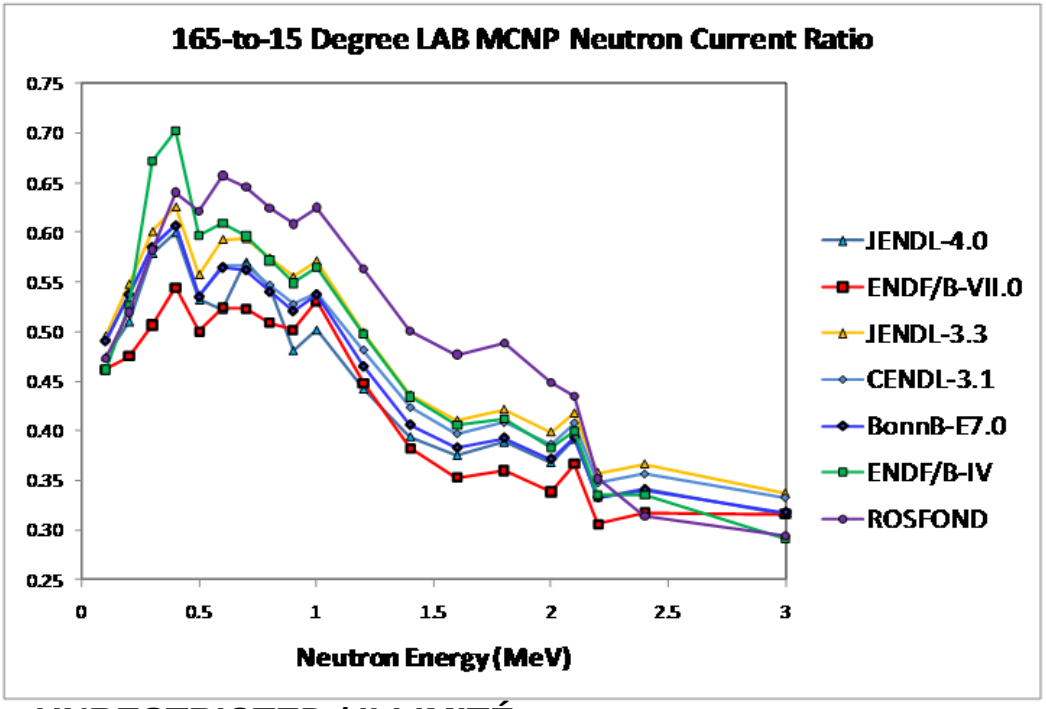




New scattering measurements on CD_2 sample at IRMM GELINA

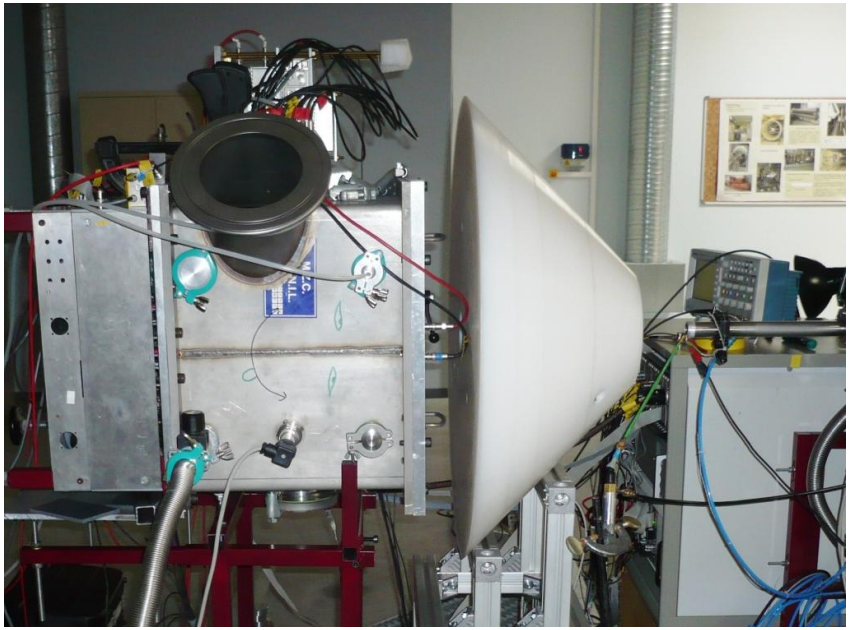
(A. Plompen, N. Nankov, C. Rouki, M. Stanoiu)

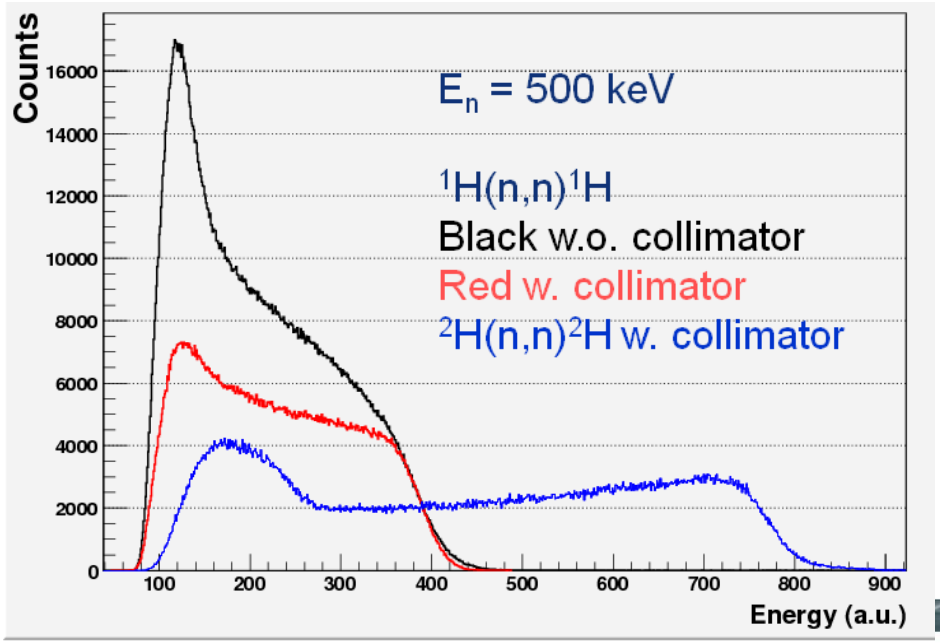
- Simulations of neutron current ratios indicate good sensitivity to ^2H nuclear data libraries at extreme backward & forward angles
- Measurements performed for CD_2, C & blank with Li-glass detectors at 15˚ & 165˚; analysis in progress
- Will discuss at **Workshop on Elastic and Inelastic Neutron Scattering (WINS), Strasbourg, France, 6-7th Dec. 2010**



New deuterium recoil measurements

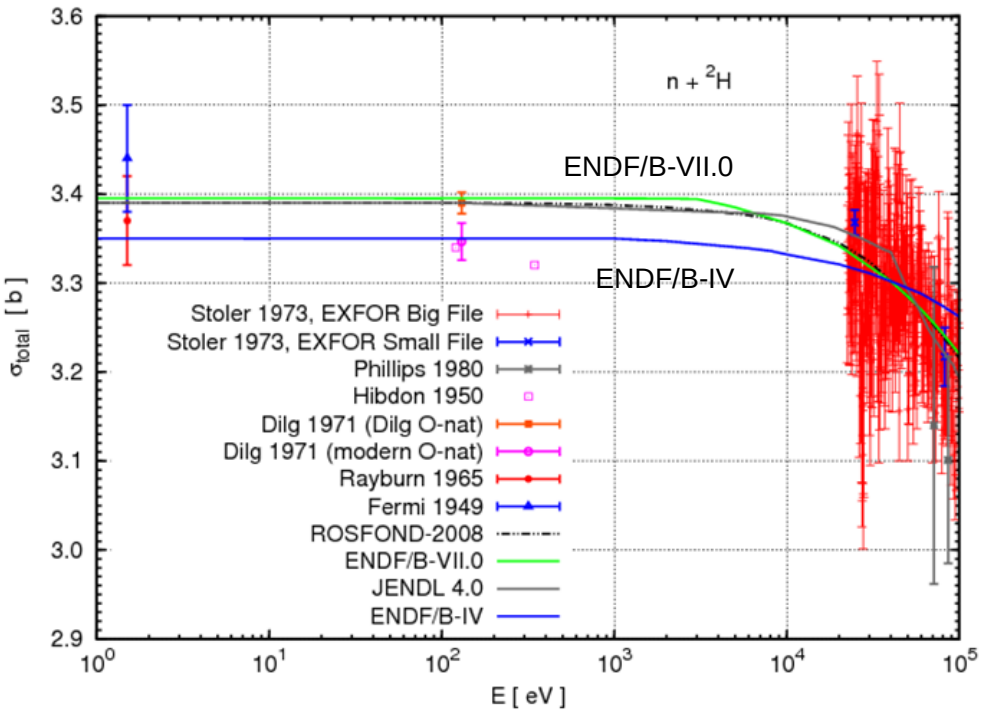
- **CENBG Bordeaux** (CNRS/IN2P3) - EFNUDAT funded experiment, Li(p,n) neutrons from AIFIRA VdG/Pelletron; **Time projection chamber**
- CNRS involvement: Bertram Blank, Pauline Ascher, Charles Eduard Demonchy, Teresa Kurtukian-Nieto, Beatriz Jurado, Mourad Aïche, Antoine Bacquais, Jerome Giovinazzo, 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

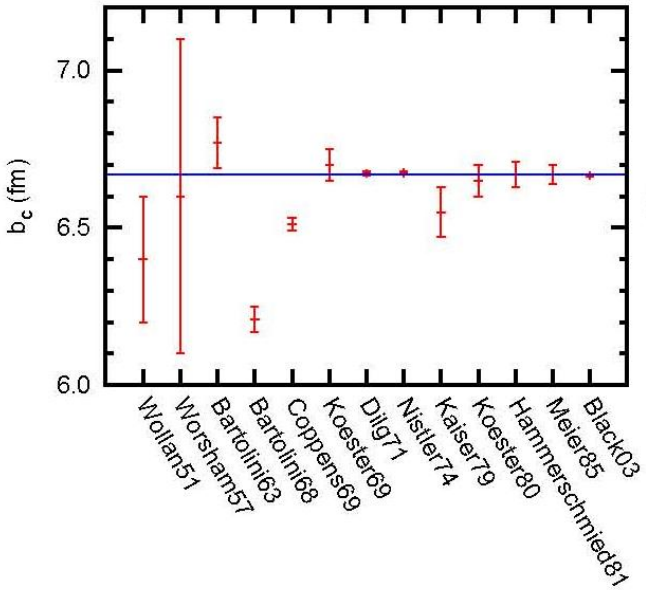




^{2}H scattering cross section at low E

- σ_s = **3.390** $\pm$ 0.012 b, based on Dilg (1971) measurements of total cross section for D_2O, SiO_2 & Si at 130 eV
  - Schoen/Black et al. (2003) n-interferometer b_{nd} measurements support this
- But, modern O values would reduce this by **1.3%** to **3.344 b**
  - Modern ^{1}H data are reduced by **0.3%** relative to Dilg H_2O & other measurements (1975)





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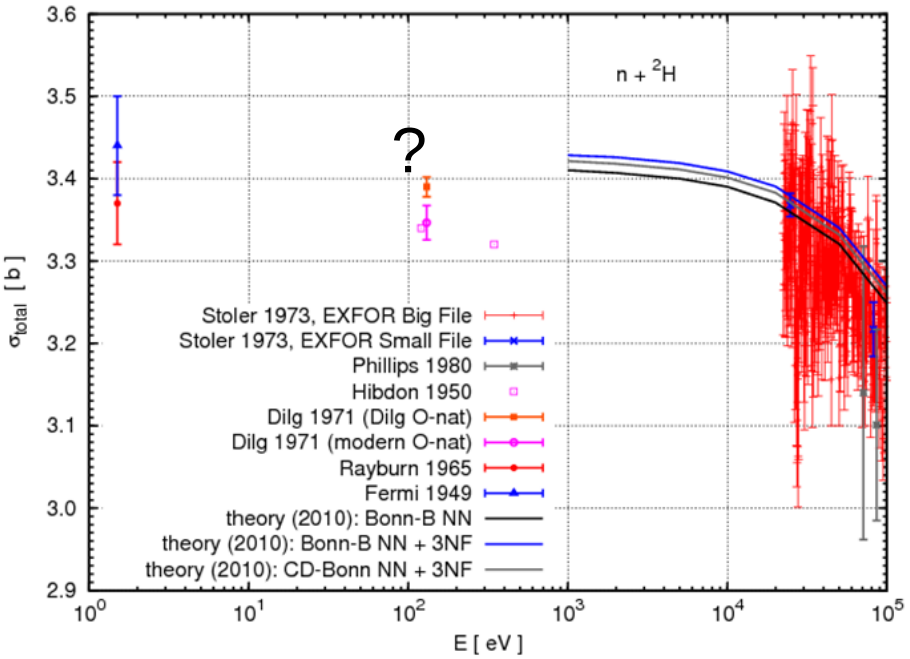
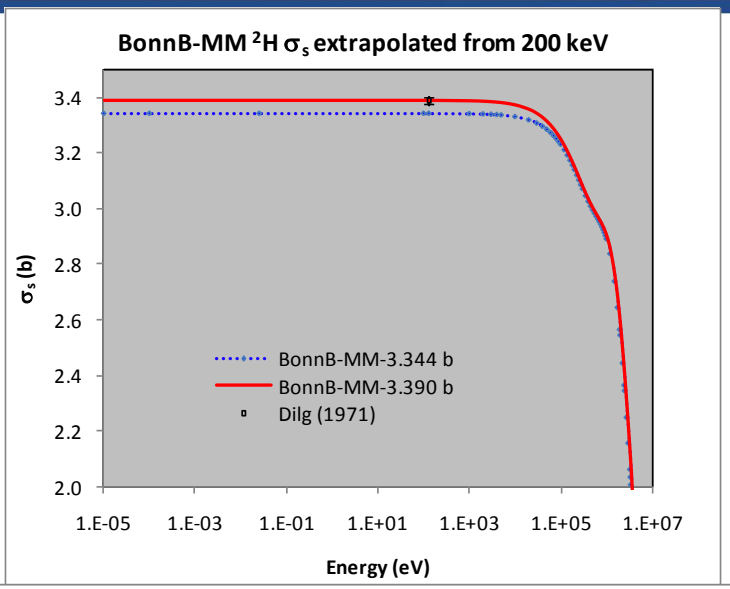
Nuclear-theory based ^{2}H scattering cross section

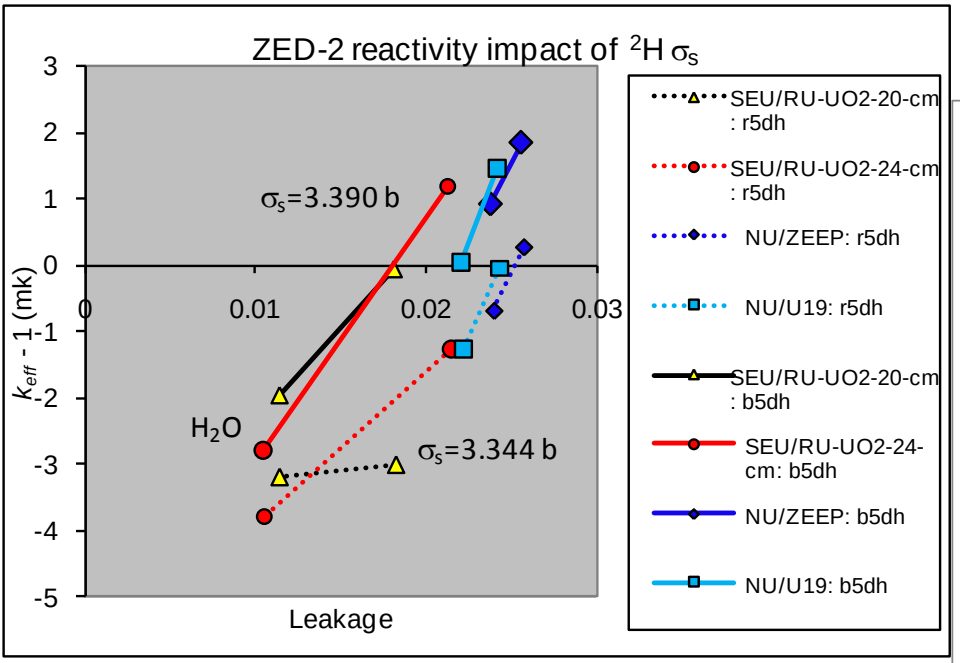
- Derived from doublet ($^2a_{nd}$) & quartet ($^4a_{nd}$) scattering lengths: $\sigma = \frac{8\pi}{3}\left(\frac{1}{2}\,{}^2a_{nd}^2 + {}^4a_{nd}^2\right)$
- Results vary significantly
  - Fujiwara & Fukukawa (2010) values give 3.3085 b **(-2%)**
  - Garcilazo &Valcarce (2007) values give 3.4849 b **(+3%)**
  - Witala (2003) values range from 3.3638 b **(-0.6%)** to 3.4450 b **(+1.6%)**
  - Schoen (2003) lists values for $^2a_{nd}$ from -6.4 to +1.76 fm
- New transmission σ_{tot} measurements <20 keV are suggested to reduce uncertainty, possibly using CD_2 sample at GELINA

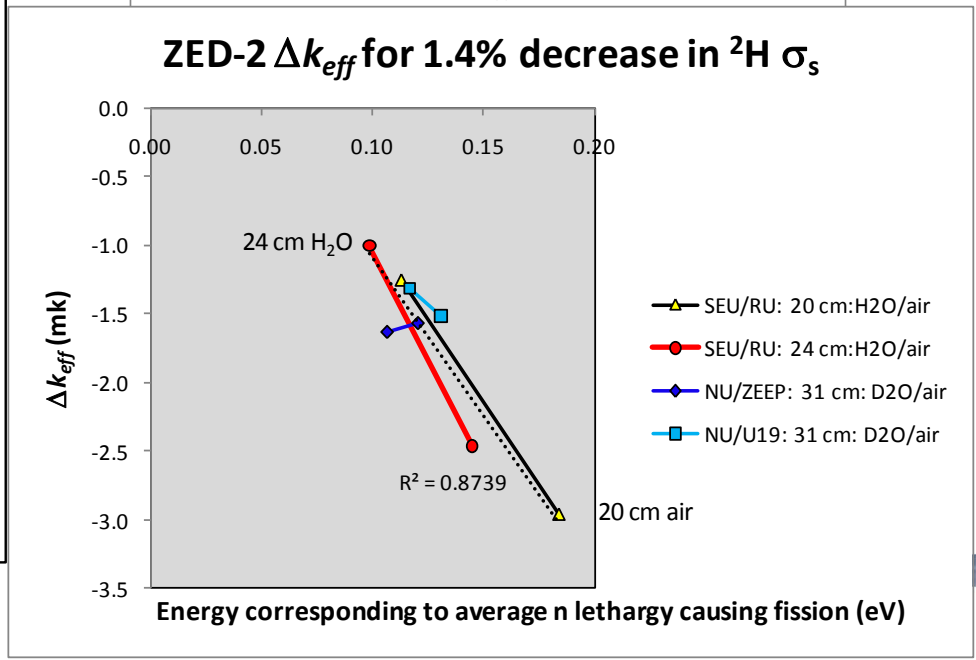


ZED-2 reactivity impact of ^2H scattering cross section (BonnB-MM with 3.390 b vs. 3.344 b)

- ZED-2 k_{eff} & Coolant Void Reactivity (CVR) simulation bias values sensitive to ^2H σ_s at low E
  - ❑-0.7 to -2.2 mk per % decrease in σ_s
  - ❑Largest Δk_{eff} for hardest spectrum
- Qualitatively consistent with TSUNAMI analysis







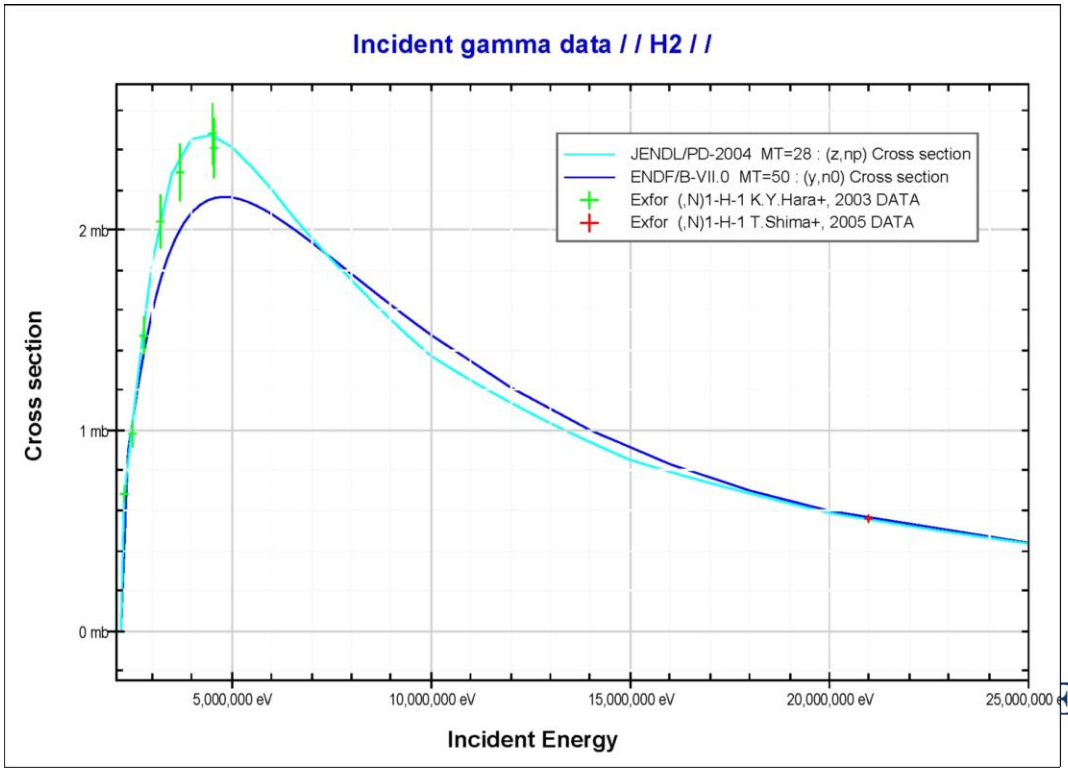
^{2}H thermal capture cross section

- Increase from **0.508 mb** to **0.549 mb (+8.1**%; due to increase for ^{12}C, Firestone CSEWG 2009) has small impact
  - About -1.0 mk for HST-004
  - About -0.4 mk for ZED-2, but negligible impact on CVR bias
- Nuclear theory seems to support larger values
  - Viviani et al. (1996) gives:

    0.600 mb for AV14/VIII model & 0.578 mb for AV18/IX model
- JENDL-4.0 uses **0.550 mb**

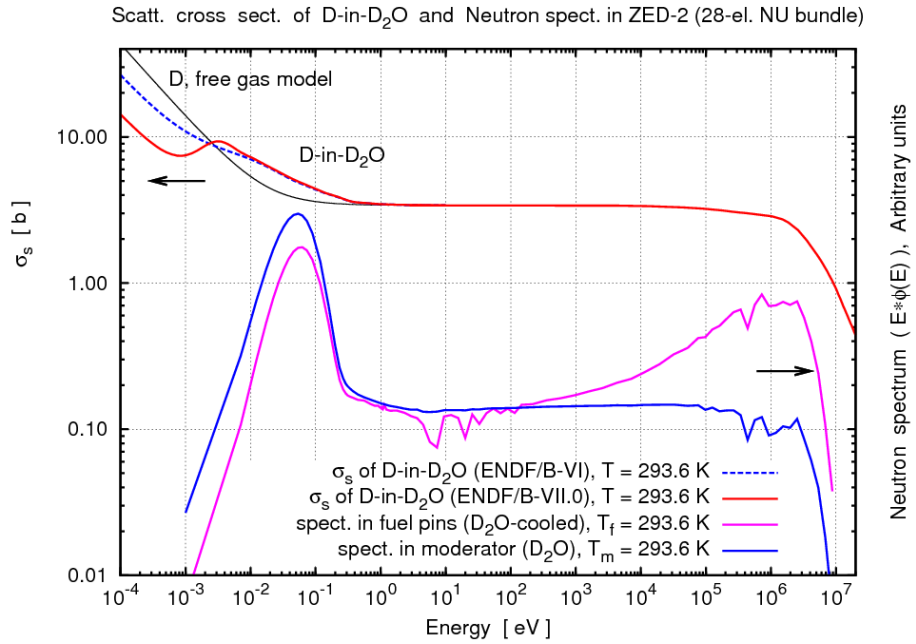
^{2}H photonuclear data (>2.2246 MeV threshold)

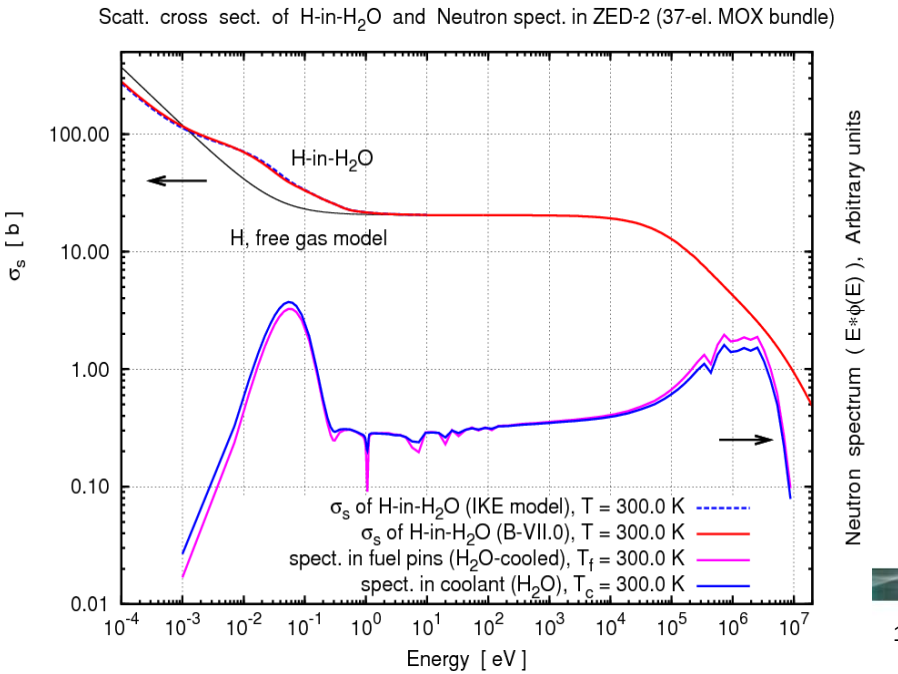
- Including photonuclear data has a small (**0.4 to 0.7 mk**) impact on k_{eff} (94% due to ^{2}H), but little impact on ZED-2 CVR bias
- Increase in **JENDL PD-2004** ^{2}H to match Hara (2003) data increases photoneutrons by 13%, but $\Delta k_{eff} < 0.2$ mk



ZED-2 sensitivity to Thermal Scattering Law (TSL) data

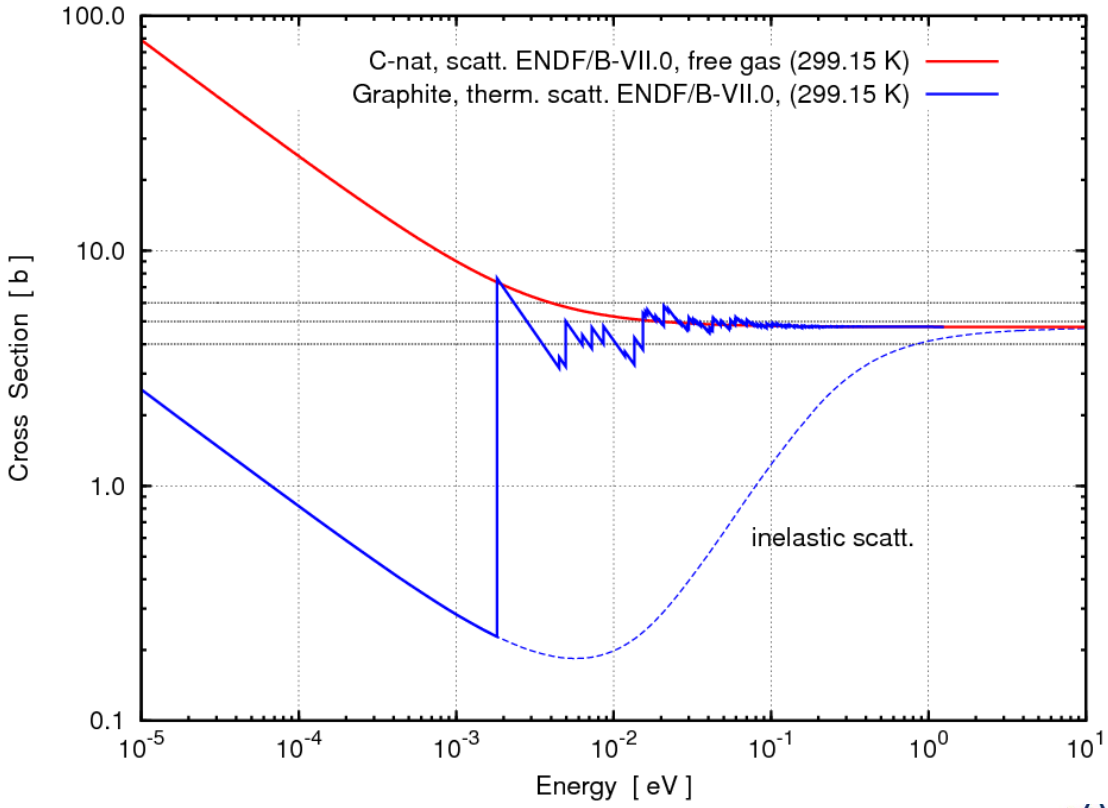
- Critical lattices of U-nat/LEU fuel in channels with D_2O/H_2O/air coolant, D_2O moderator & graphite reflector at room temperature
- **D_2O** TSL reactivity worth ranges from **-0.5** to **+6** mk
- **H_2O** TSL worth is **+12** to **+16** mk for H_2O coolant
  - H_2O cooled cases sensitive to temperature representation; -0.7 mk in k_{eff} (+0.6 mk in CVR bias) for 5.5˚C change
  - H impurity in D_2O moderator modelled as H_2O (no TSL data for **HDO**); worth 0.0 to +0.9 mk; some indication of bias trends with impurity level





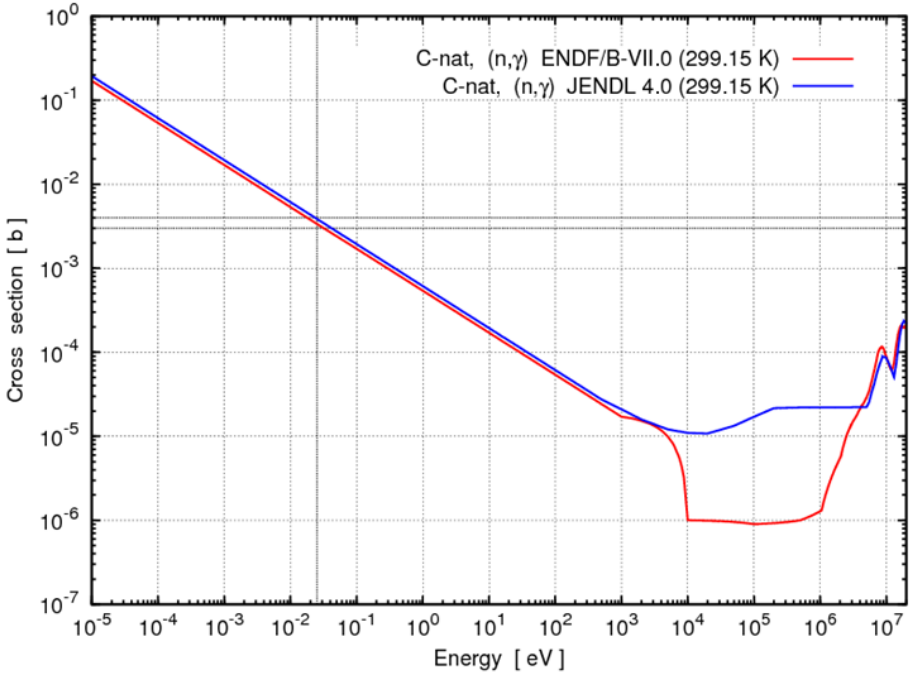
Graphite TSL

- ZED-2 reflector graphite UK ‘reactor’ grade 1.63 g/cm^3
- ZED-2 sensitivity to graphite TSL 0.0 to +0.4 mk in k_{eff}
- CVR bias reduced by 0.2 mk if TSL is turned off



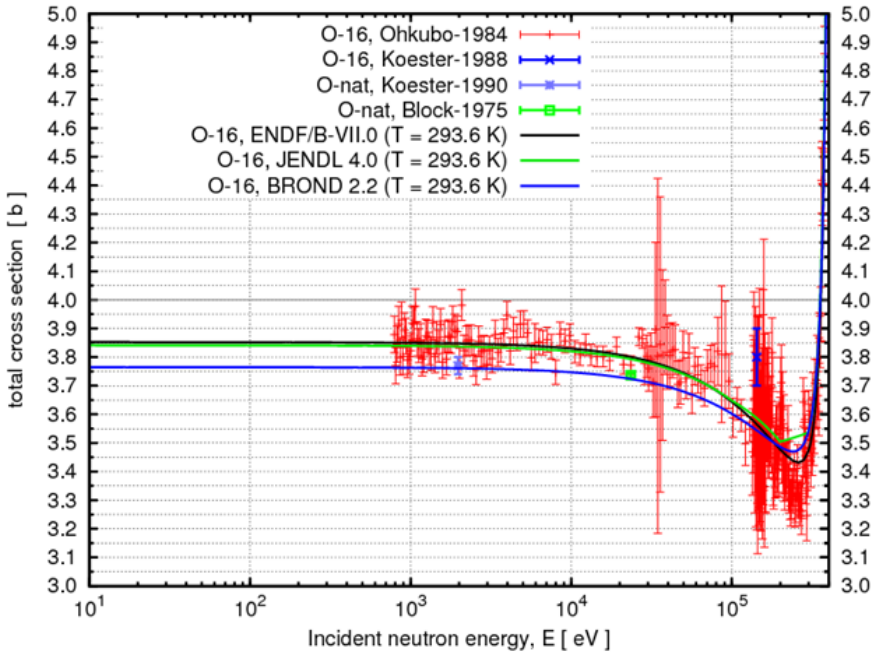
Carbon thermal capture cross section

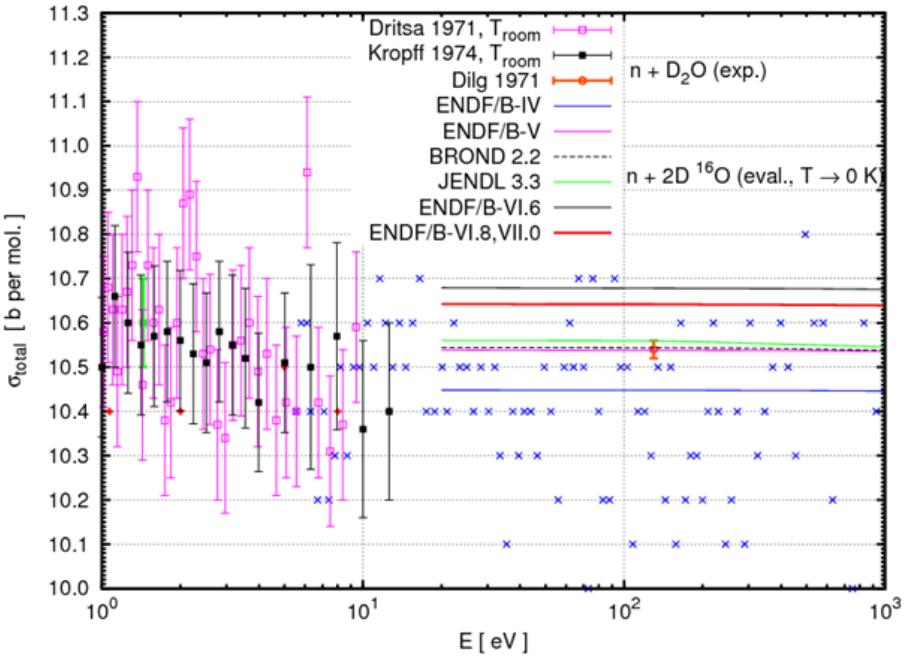
- Firestone's ^{12}C thermal capture cross section value **3.84(6) mb** (**9%** higher than ATLAS **3.53(7) mb**) & ^{13}C **1.51(3) mb** (**10%** higher than ATLAS **1.37 mb**)
- Estimate for C-nat is **3.814 mb** [0.9889*3.84 + 0.0111*1.51 mb]
- JENDL-4.0 uses **3.86 mb** for C-nat
- ENDF/B-V to VII.0 is **3.36 mb (-12%)** for C-nat (?)
- New estimate reduces ZED-2 k_{eff} by 0.1 to 0.3 mk



Oxygen thermal scattering cross section

- Thermal σ_s for ^{16}O increased to match Ohkubo (1984) σ_{tot} data
  - ENDF/B-VII.0, ROSFOND: **3.852 b (+2.4%)**; JENDL-4.0: **3.841 b (+2.1%)**
  - ATLAS/Dilg (1971): **3.761 ± 0.006 b (±0.2%)**
- Derived coherent scattering length b_{coh} are also discrepant
  - ENDF/B-VII.0, ROSFOND: **5.875 fm (+1.2%)**; JENDL-4.0: **5.866 fm (+1.1%)**
  - ATLAS/Koester (1991)**: 5.805 ± 0.005 fm (±0.1%)**
- D_2O σ_{tot} data seem to support lower ATLAS value for ^{16}O
- New ^{16}O measurements are suggested <10 keV, if feasible



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