Inelastic neutron scattering cross-section measurements on ^{7}Li and ^{63,65}Cu

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Joint Research Centre
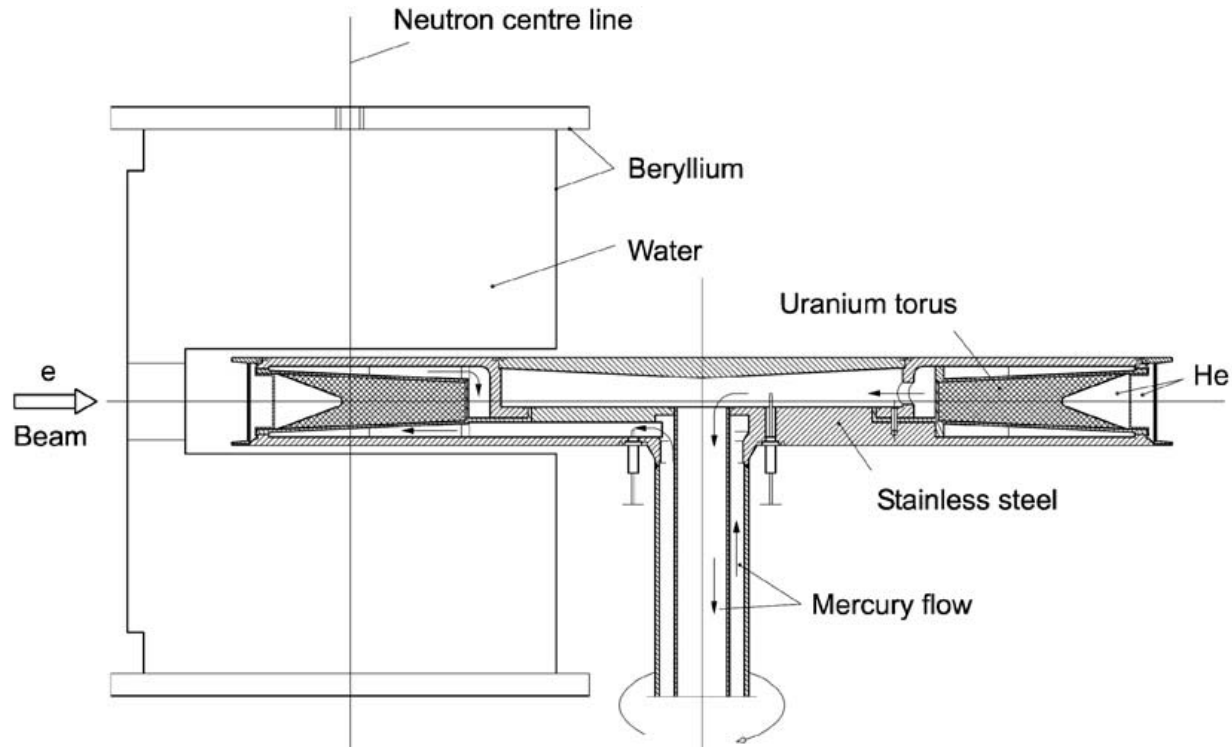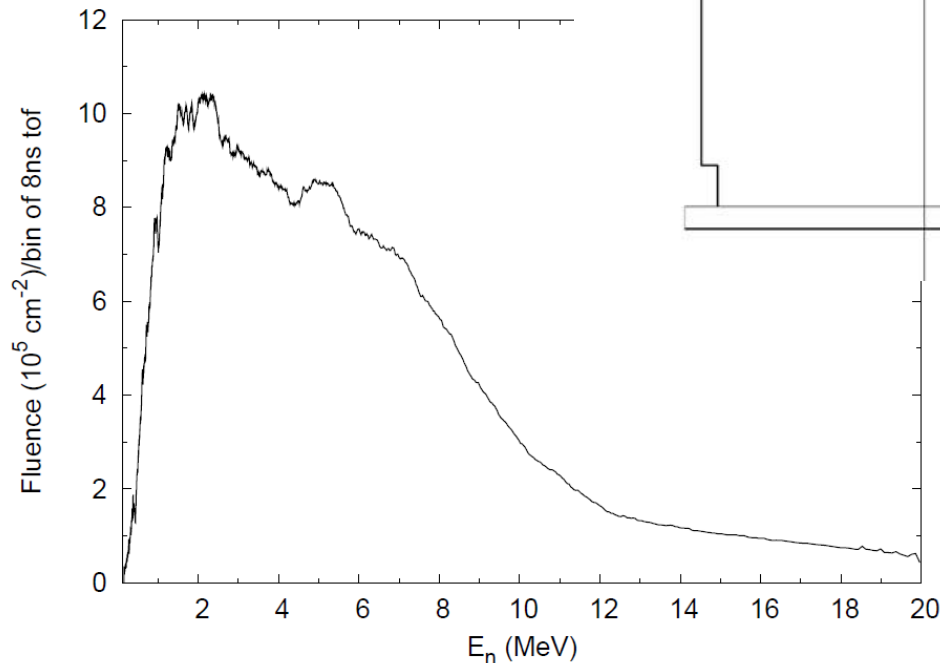the European Commission's
in-house science service

The GELINA facility

- **G**eel **E**lectron **LIN**ear **A**ccelerator
- Pulsed white neutron source (800 Hz), FWHM < 1 ns
- Neutrons produced in the ^{dep}U target by photon induced reactions
- Flight paths from 8 m up to 400 m in length
- The inelastic scattering experiments discussed here were done at FP3, 200-m and 100-m measurement stations

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The GELINA target

- Hg-cooled rotating ^{dep}U target
- Both fast and moderated neutrons available

Labels on diagram: Neutron centre line, Beryllium, Water, Uranium torus, He, Stainless steel, Mercury flow, e Beam

Graph axes: Fluence (10^5 cm^{-2})/bin of 8ns tof vs E_n (MeV)

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The GAINS spectrometer

- 12 HPGe detectors, about 100% relative efficiency
- Detectors at 110°, 125°, and 150°, four detectors at each angle
- Fission chamber upstream from the sample position to monitor the neutron flux
- 8 UF4 deposits (Ø 70 mm) on 5 Al foils (20 μm)
- 3 Acquiris DC440 digitizers, 12 bit amplitude resolution, 440 MS/s

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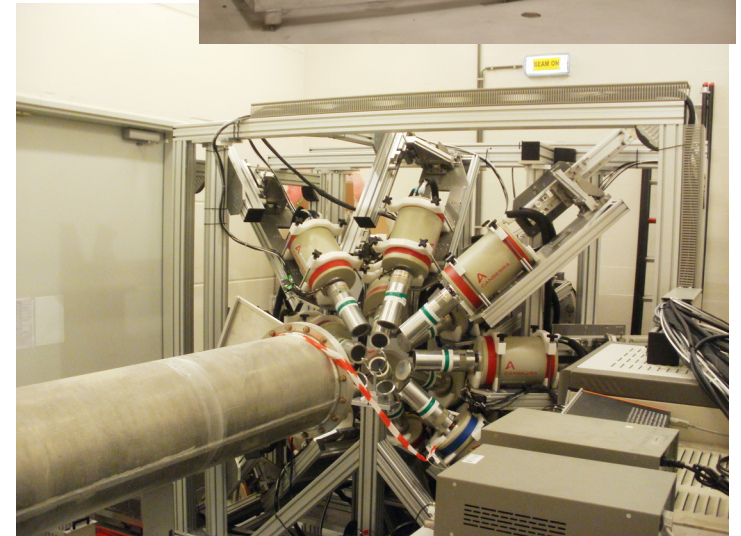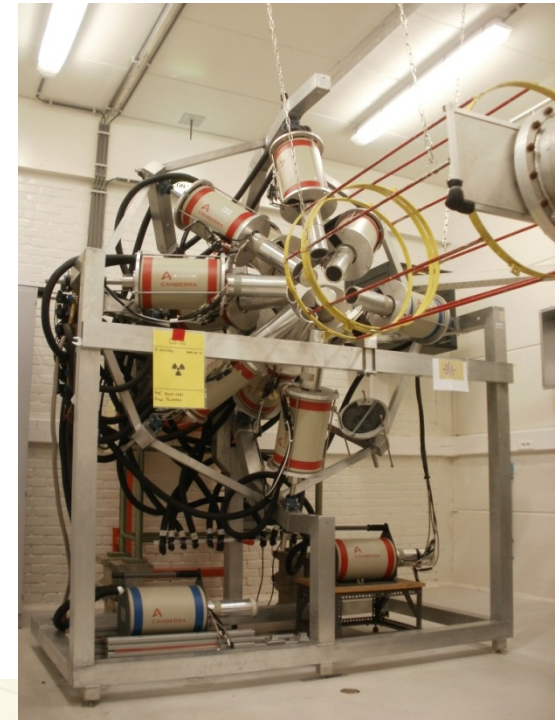
Inelastic neutron scattering by ^{7}Li

- The γ-ray production cross section of the 477.6-keV $1/2^- \rightarrow 3/2^-_{g.s.}$ transition is a good candidate to be used as a standard:
  - **Isotropic γ-ray emission**
  - **Negligible IC coefficient**
  - **Low inelastic threshold (546 keV)**
  - **Fairly smooth energy dependence of the cross section**
  - **Material readily available as LiF optical windows**
  - **Issues: $^{11}B(n,\alpha\gamma)^7Li$ (boron shielding), isotopic composition determination**

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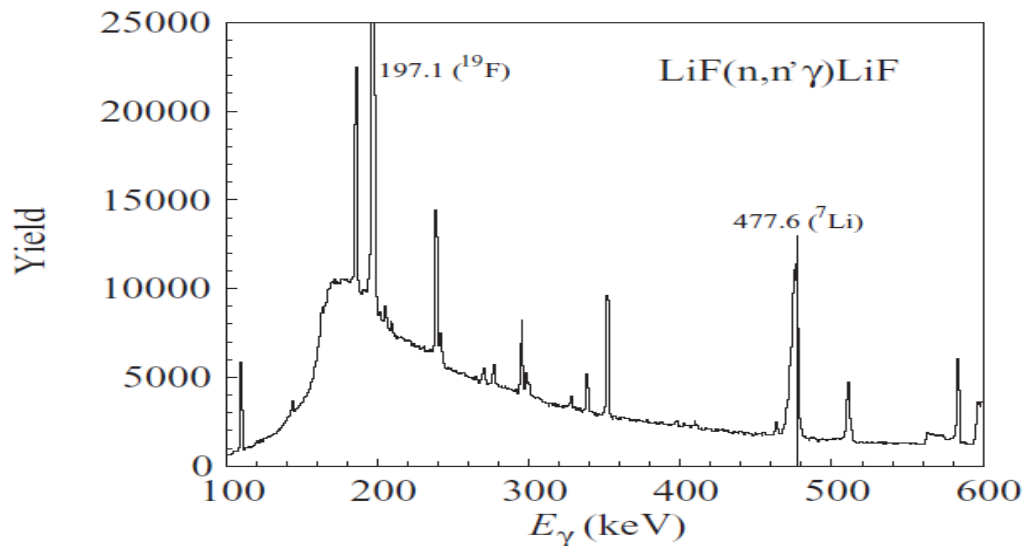
Inelastic neutron scattering by ^{7}Li

- Two experiments done at EC-JRC-Geel in 2015:
  - **FP3/200m, 398 hours, old GAINS frame**
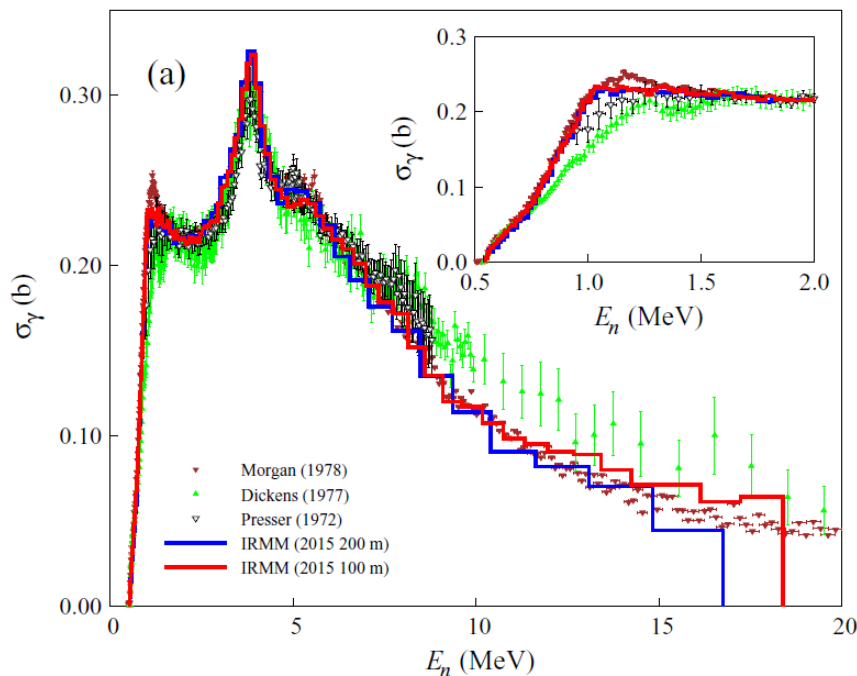 - **FP3/100m, 380 hours, new GAINS frame**
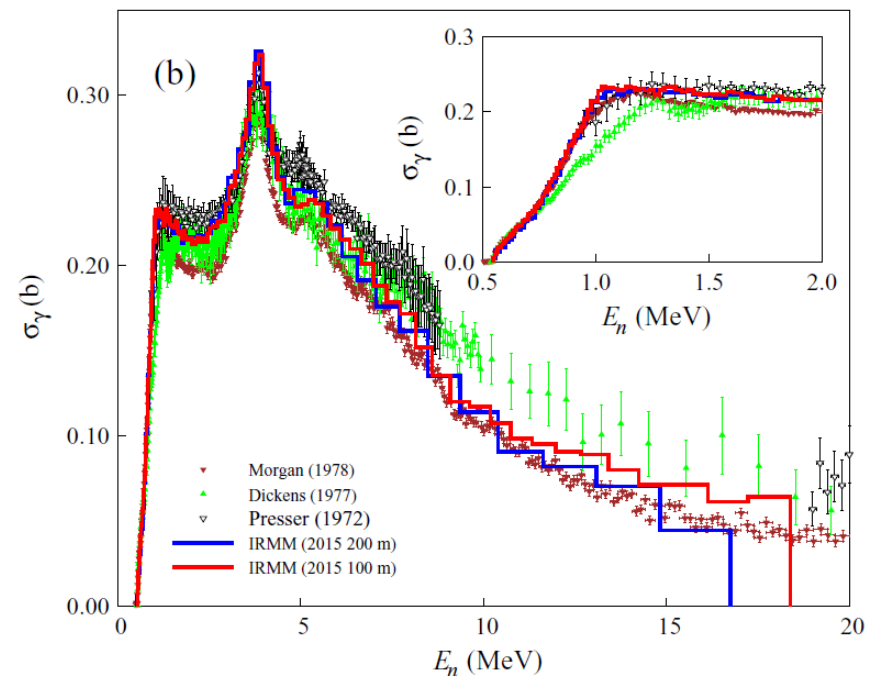
M. Nyman *et al*., Phys. Rev. C 93, 024610 (2016)
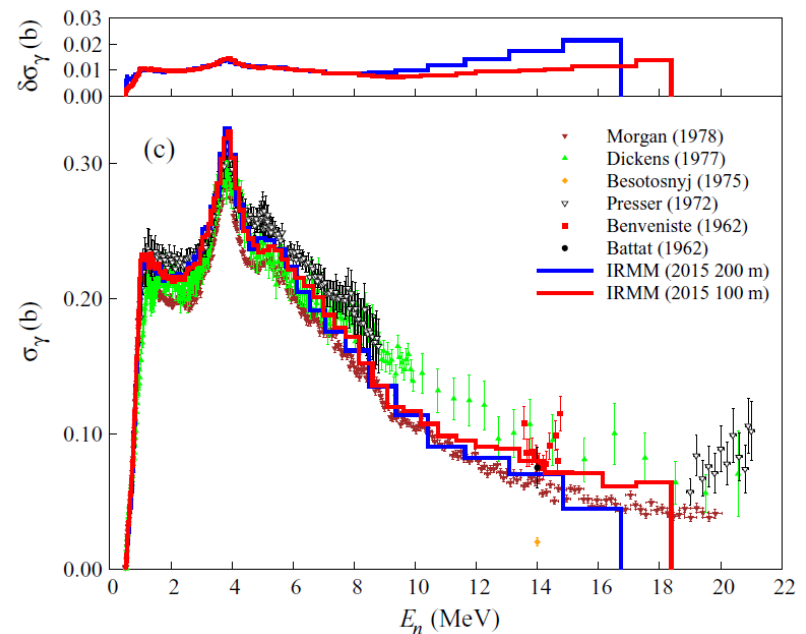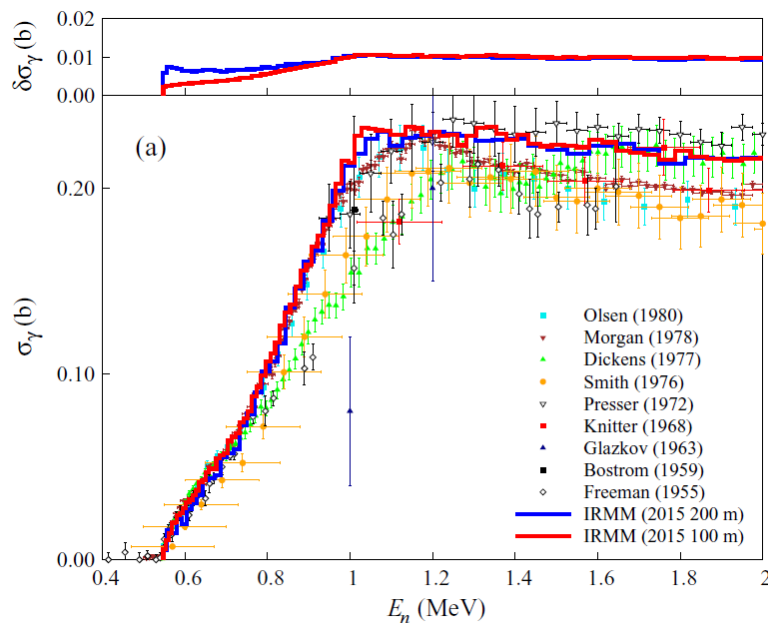
Inelastic neutron scattering by ⁷Li

- To investigate the compatibility of different data sets, they were normalized to match at different energies
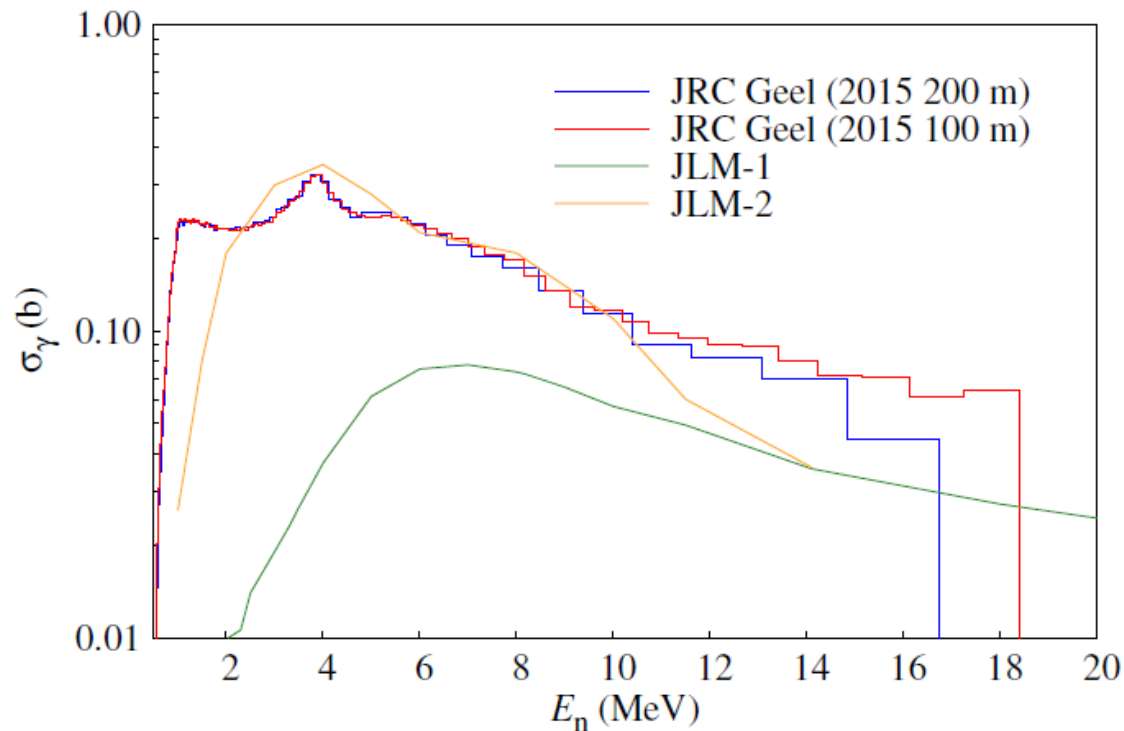- Best agreement was found for E = 2 MeV

Normalized   Unnormalized

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Inelastic neutron scattering by ⁷Li

- Non-discrimination coupled-channels (CDCC) calculations

D. Ichinkhorloo *et al*., Phys. Rev. C 93, 064612 (2016)

Inelastic neutron scattering by ⁷Li

- Still discrepancies in the ^{7}Li$(n,n'\gamma)^7$Li cross section between experimental data sets

  $\rightarrow$ A new measurement at nELBE scheduled later this year using LaBr$_3$ and HPGe detectors

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Inelastic neutron scattering by ^{63,65}Cu

- Experiments for studying very rare processes (like $2\beta0\nu$) require greatly reducing the background
- Copper is a common shielding and structural material used in e.g. COBRA, CUORE, EXO, GERDA, and MAJORANA
- Understanding the background contribution from neutron interactions in Cu is important when searching for very weak experimental signals
- Also relevant to fusion research: Cu widely used in tokamaks (heat sink components, magnets,…)

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Inelastic neutron scattering by ^{63,65}Cu

- Three experiments performed at EC-JRC-Geel:
  - **Two enriched samples in 2013 at FP3/200m** (electronics problem affected *n*-flux monitoring)
  - **^{nat}Cu in 2015 at FP3/100m** (this can be used to normalize the cross sections from the two previous experiments)
- Data analysis of the ^{nat}Cu experiment is in progress
- Normalization of the ^{63,65}Cu to be done
- Preliminary results will be presented here, full publication planned for 2017

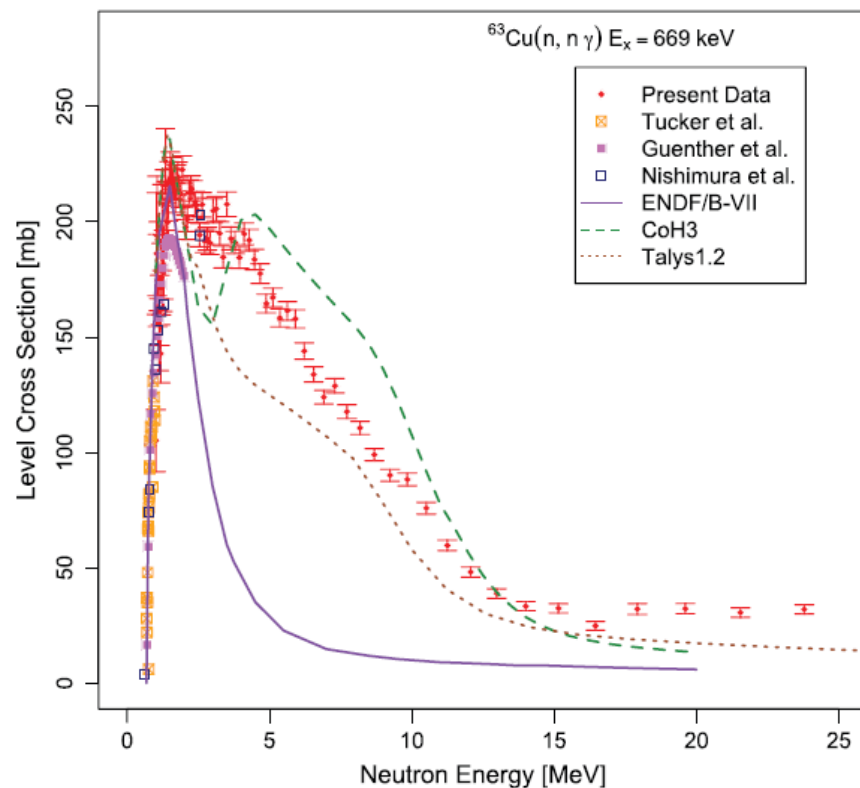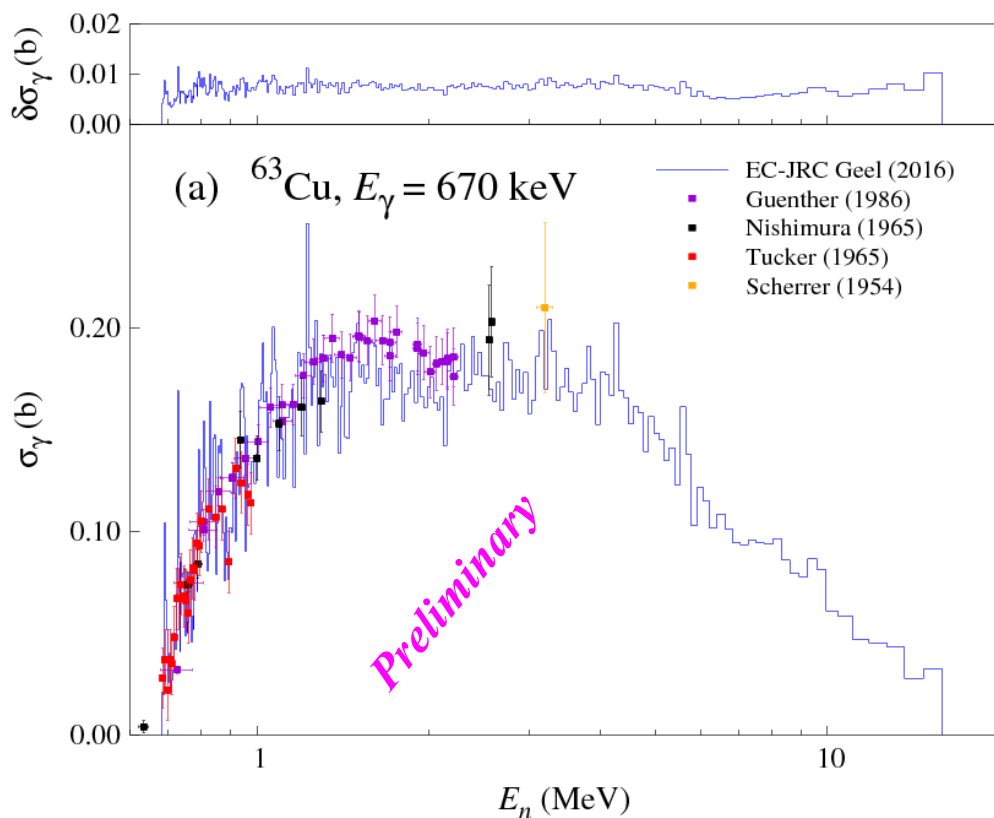European Commission

Inelastic neutron scattering by ^{63,65}Cu
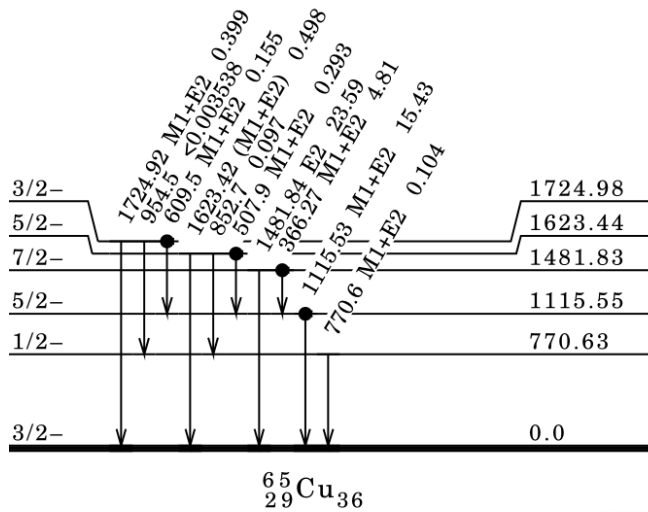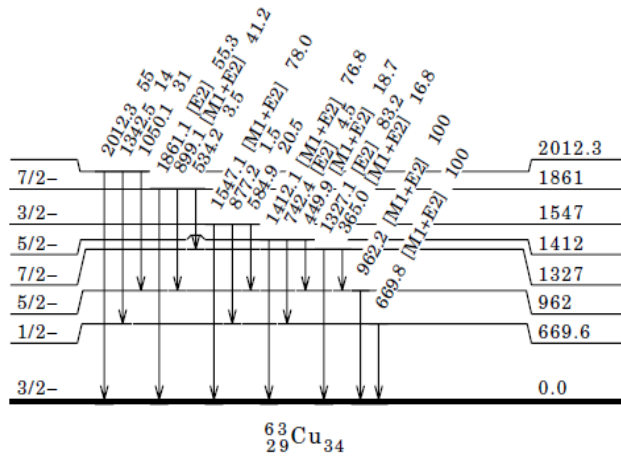
- Overlaid γ-spectra from the three measurements, plus background:
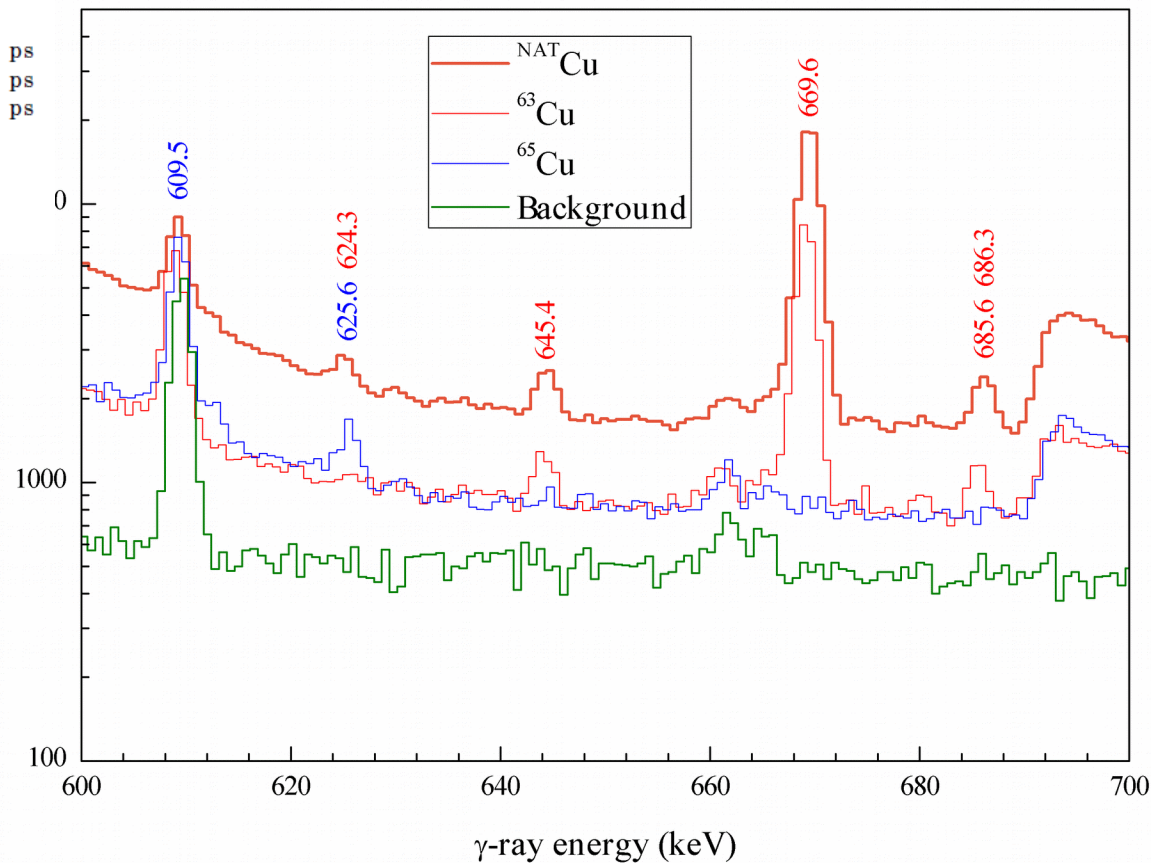
Inelastic neutron scattering by ^{63,65}Cu

- The γ-ray production cross section for the first transition in ^{63}Cu:

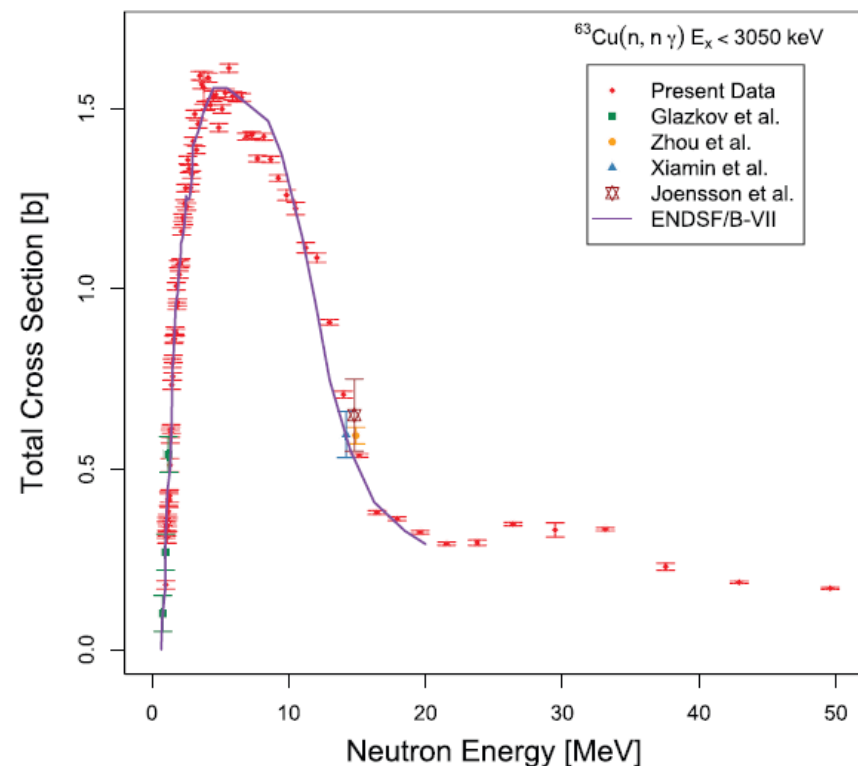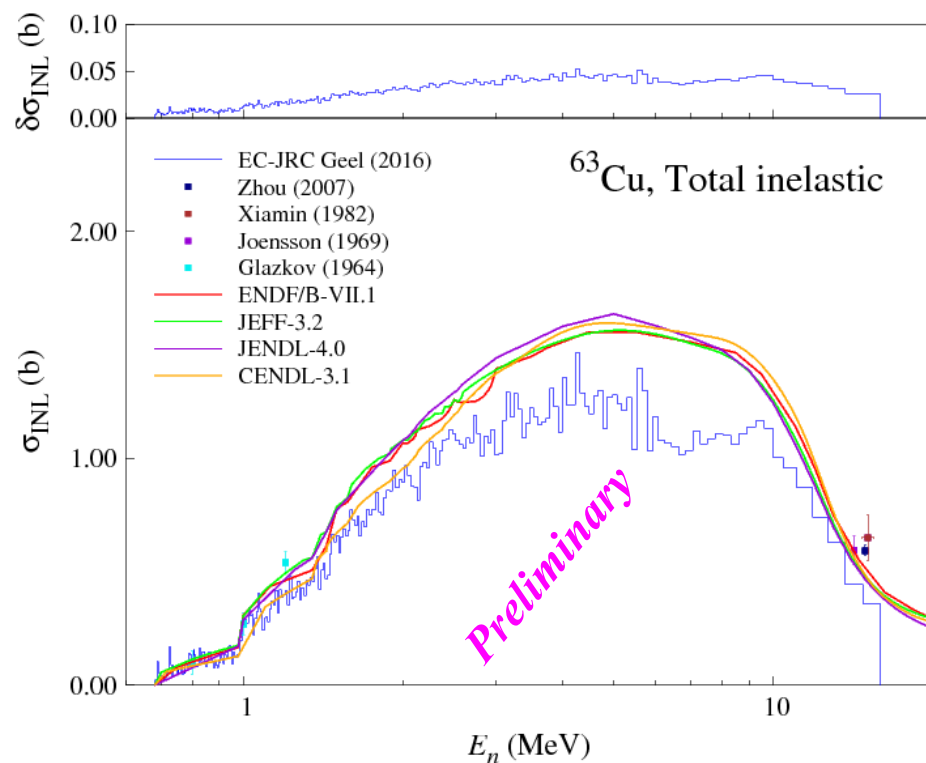M. S. Boswell *et al.*, Phys. Rev. C 87, 064607 (2013)

Inelastic neutron scattering by ^{63,65}Cu

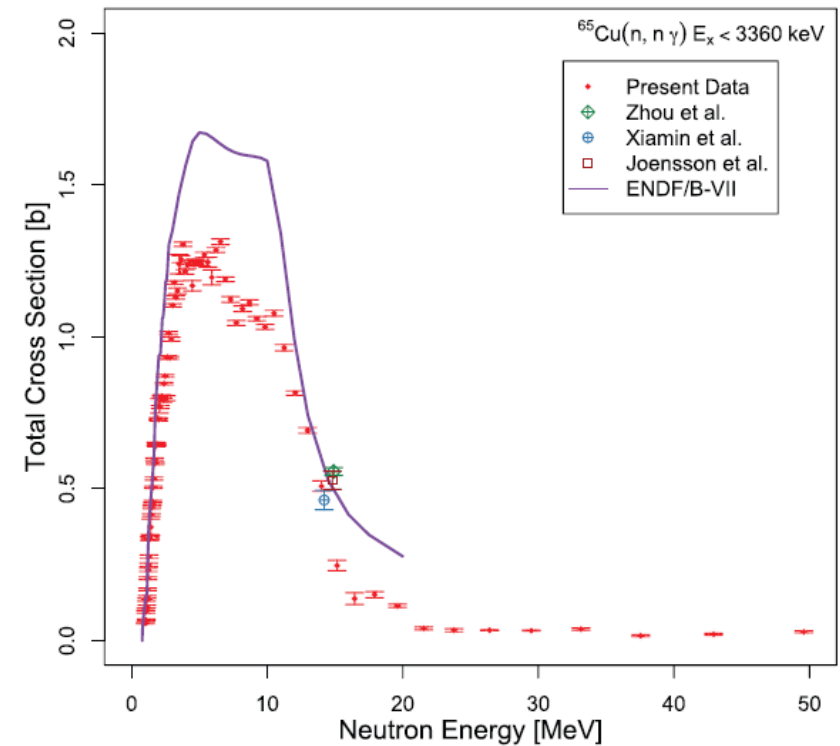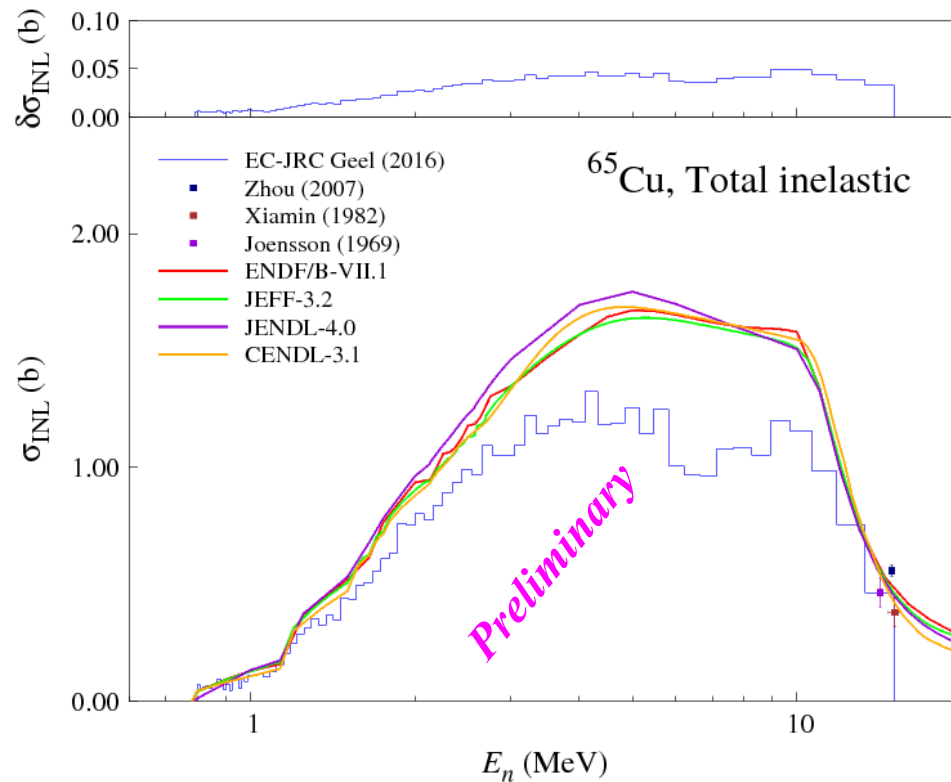- The total inelastic neutron scattering cross section for ^{63}Cu:

M. S. Boswell *et al.*, Phys. Rev. C 87, 064607 (2013)

Inelastic neutron scattering by ^{63,65}Cu

- The total inelastic neutron scattering cross section for ^{65}Cu:

M. S. Boswell et al., Phys. Rev. C 87, 064607 (2013)

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Collaboration

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Hokkaido University: D. Ichinkhorloo

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