Angular distribution measurements of neutron elastic scattering by natural carbon at GELINA with the ELISA setup

G. Gkatis[1,2], M. Diakaki[2], G. Noguere[1], A. Oprea[3], C. Paradela[3], E. Pirovano[4] , A. Plompen[1]

[1]*CEA/DES/IRESNE/DER/SPRC/LEPh, Cadarache, F-13108 Saint Paul Lez Durance, France*

[2]*Department of Physics, National Technical University of Athens, GR-15780 Athens, Greece*

[3]*European Commission, Joint Research Centre, B-2440 Geel, Belgium*

[4]*Physikalisch-Technische Bundesanstalt, D-38116 Braunschweig, Germany*

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The GELINA facility

- Pulsed white neutron source

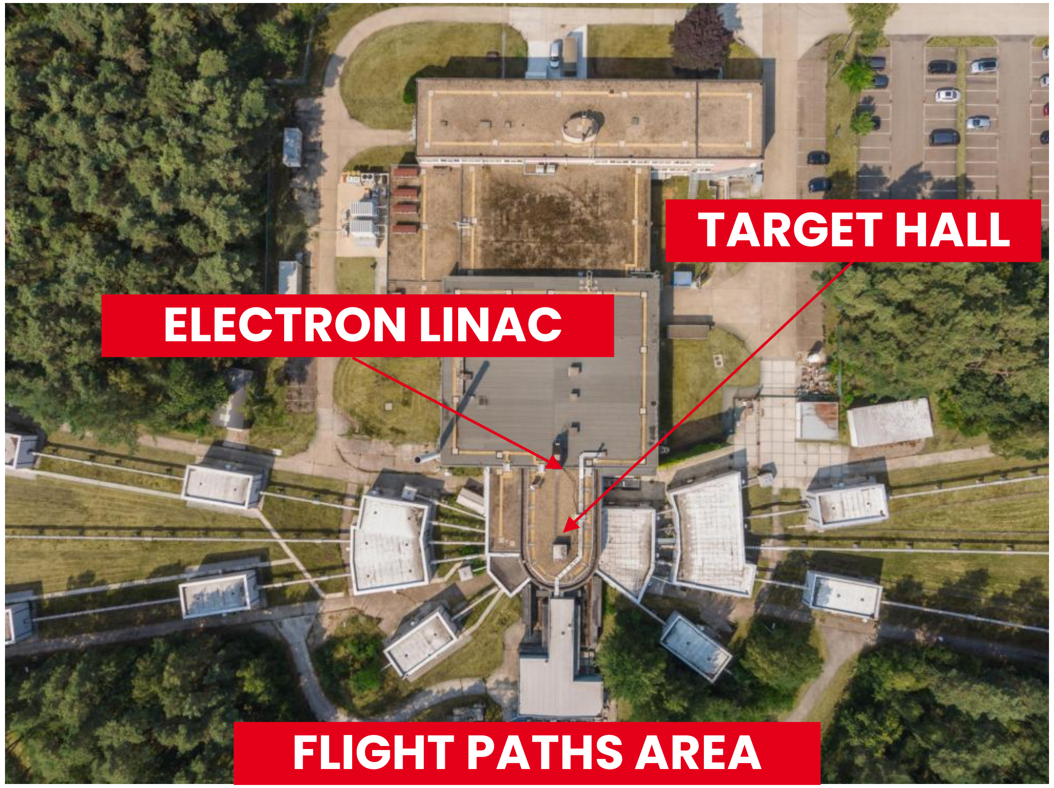
  $10\ \text{meV} < E_n < 20\ \text{MeV}$

- Neutron energy determination using the TOF (Time-Of-Flight) technique
- 10 flight paths

  Flight path length 10 m – 400 m

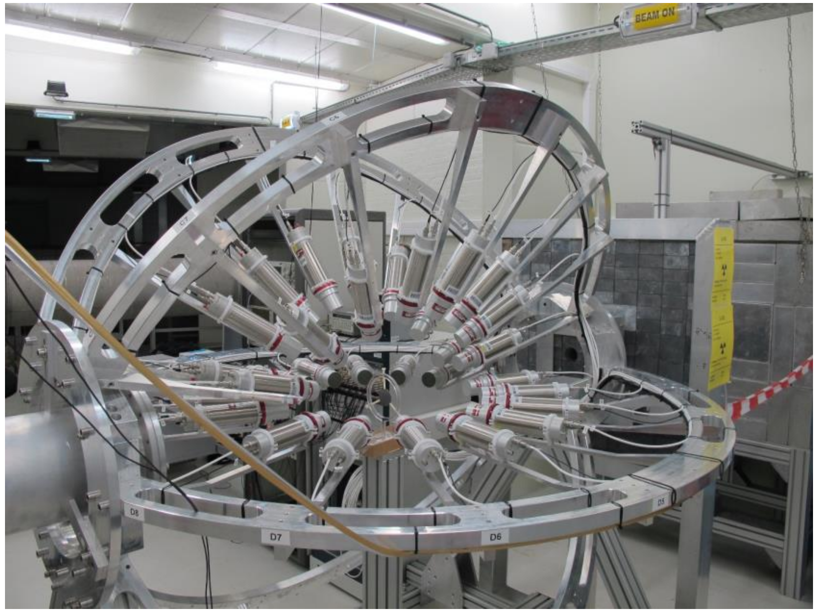
- Various experimental setups

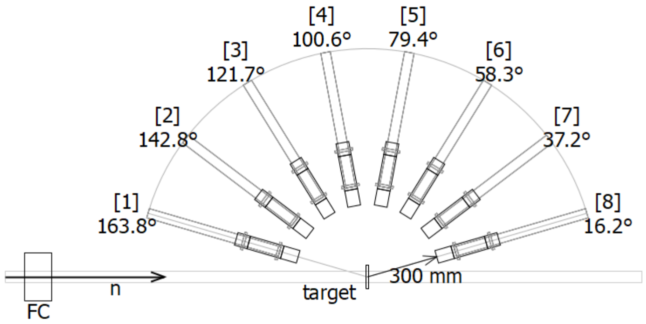
  (n,tot) – **(n,el)** – (n,inl) – (n,γ) – (n,f) – (n,cp)



The ELISA setup

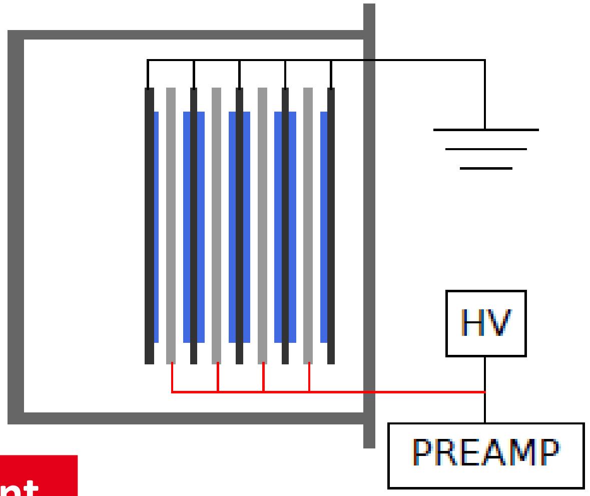
- ELISA (ELastic and Inelastic Scattering Array)
  - ^{235}**U fission chamber** (neutron flux)
  - **32 liquid organic scintillators** (scattered neutrons)
- **27.037 m** distance from the GELINA neutron source (**FP1_30m**)
- **Beam diameter** at sample position: **49 mm**
- Four sets of **8 detectors** each – mounted at specific angles
- **Digitizer-based** acquisition system + **NIM electronics** for the FC
- The goal is to produce **high-resolution cross section data** of neutron scattering in the fast neutron energy range





Fission chamber

- Parallel-plate ionization chamber
- Placed **upstream 1.37 m** from the sample
- **8 UF_4 deposits** (blue) on aluminum foils (black):
  - Al foils (84 mm diameter – 20 μm thickness)
  - **Vacuum evaporation**
  - **70 mm diameter** (> beam diameter)
  - **14 mm** distance between them
- Aluminum electrodes (grey):
  - 25 μm thickness
  - 7 mm distance from the deposits
- **P10 gas** (10% methane – 90% argon) at atmospheric pressure

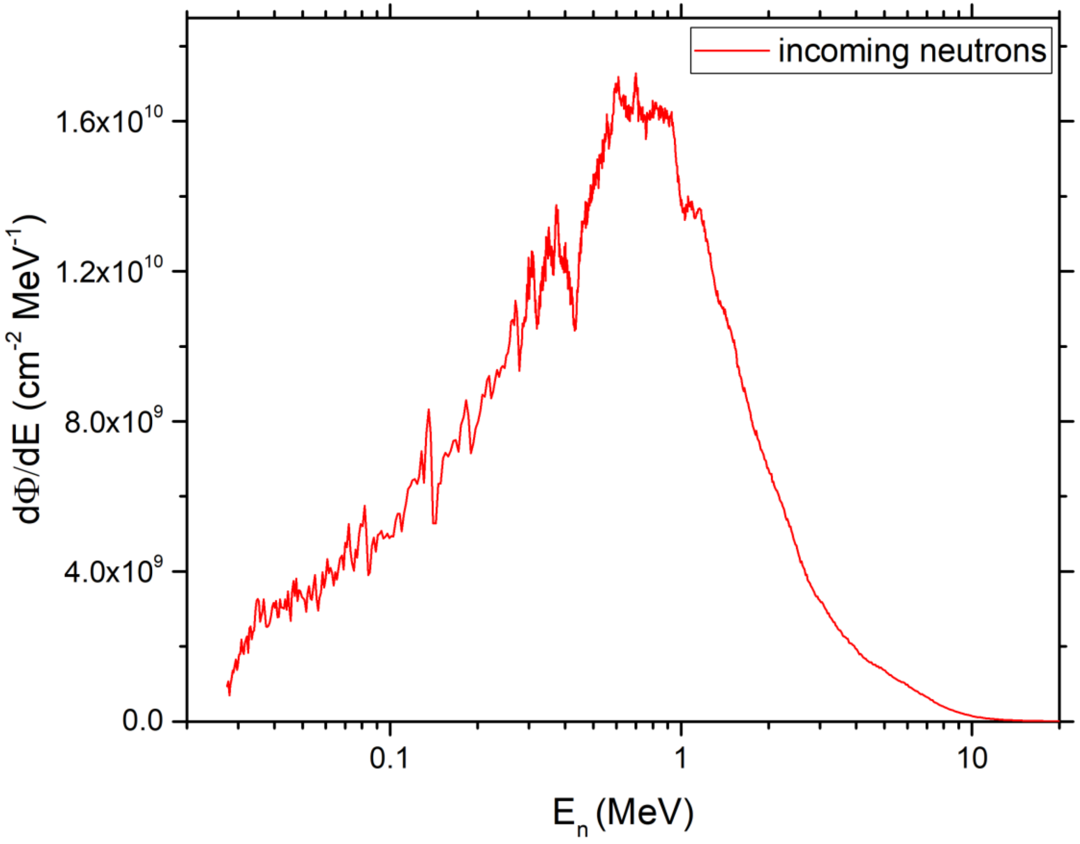


Isotope	Atomic percent
^{233}U	< 0.001
^{234}U	0.036
^{235}U	**99.94**
^{236}U	0.011
^{238}U	0.013

Neutron flux

$$\Phi(\mathrm{E}) = \frac{Y_{FC}(\mathrm{E})}{\varepsilon_{FC} \cdot \sigma_{235\mathrm{U}(n,f)} \cdot \rho_{235\mathrm{U}} \cdot A_b}$$

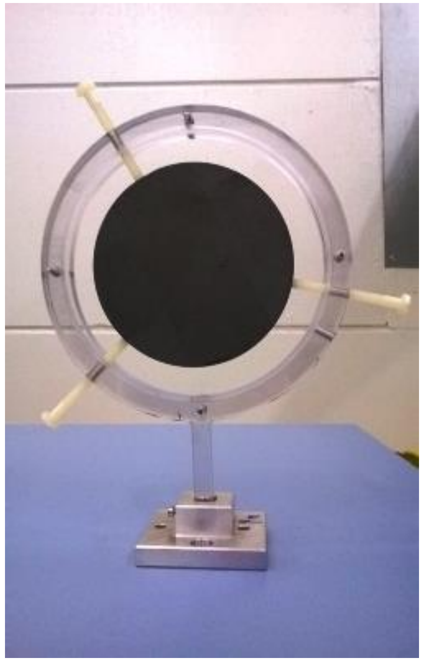
- $Y_{FC}(\mathrm{E})$: fission chamber yield
- ε_{FC}: efficiency of the fission chamber
- $\sigma_{235\mathrm{U}(n,f)}$: neutron-induced fission cross section for ^{235}U
- $\rho_{235\mathrm{U}}$: areal density of the ^{235}U targets
- A_b: cross sectional area of the neutron beam



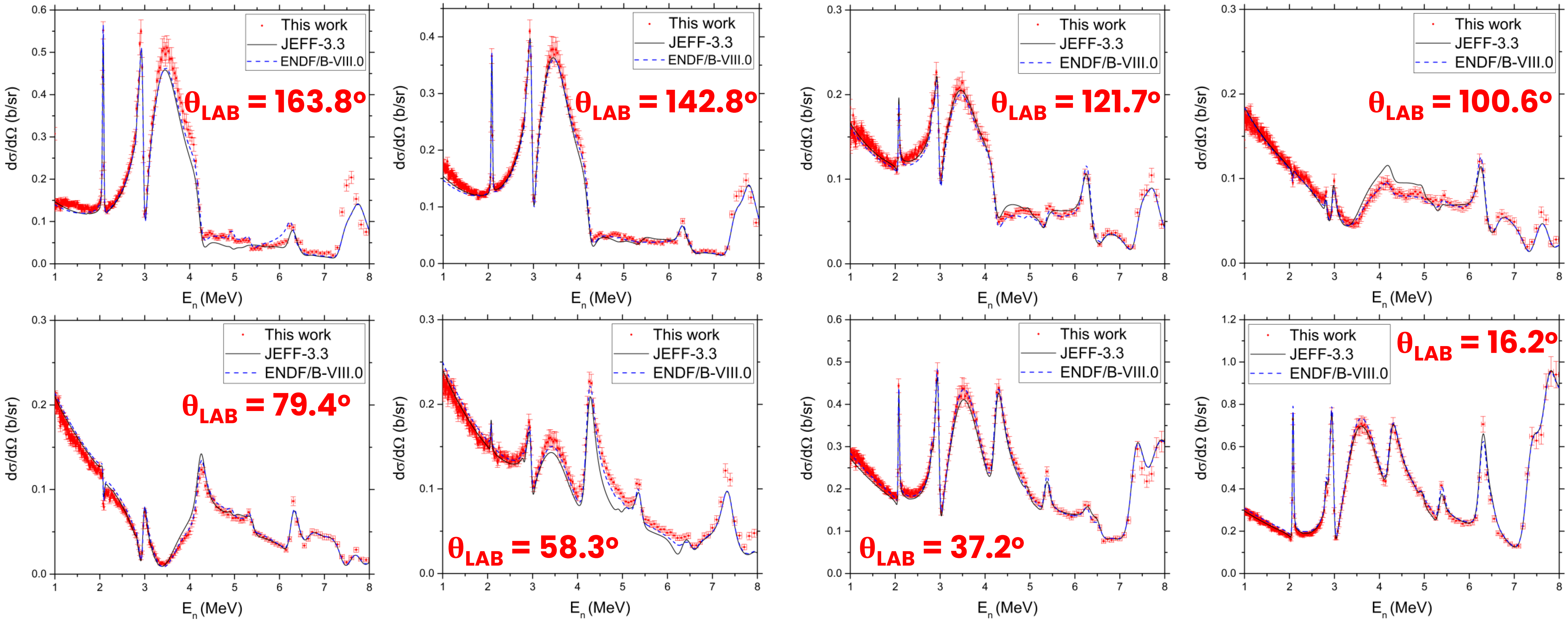
Experimental details – ^{nat}C sample

- Date: **2020**
- Duration: **600 hours** (**360** hours of **sample in** + **240** hours of **sample out** measurement for the determination of the **background contribution**)
- Resolution: **5 ns**
- **Pure ^{nat}C** sample was used:
  - Diameter: 100 mm
  - Thickness: 2.0 mm
  - Mass: 35.7 g

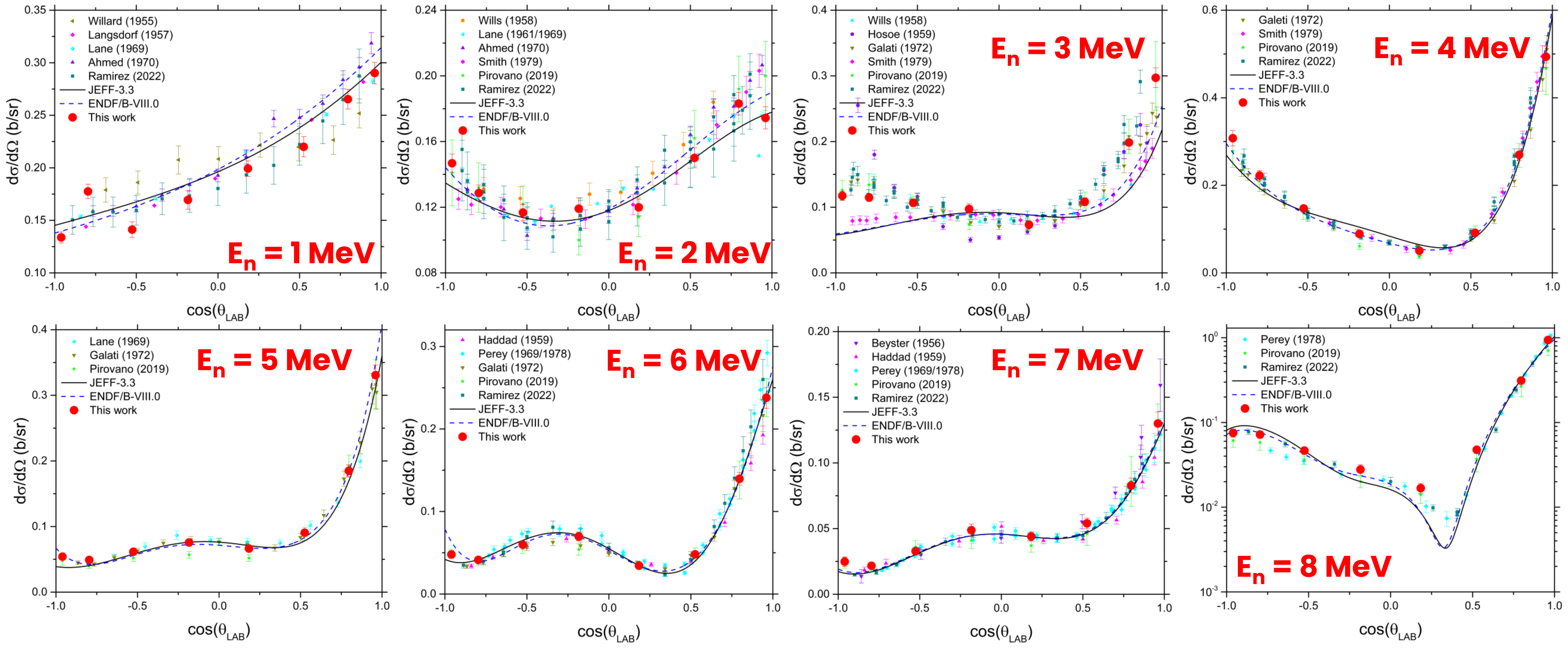
Isotope	Atomic percent
^{12}C	98.94
^{13}C	1.06



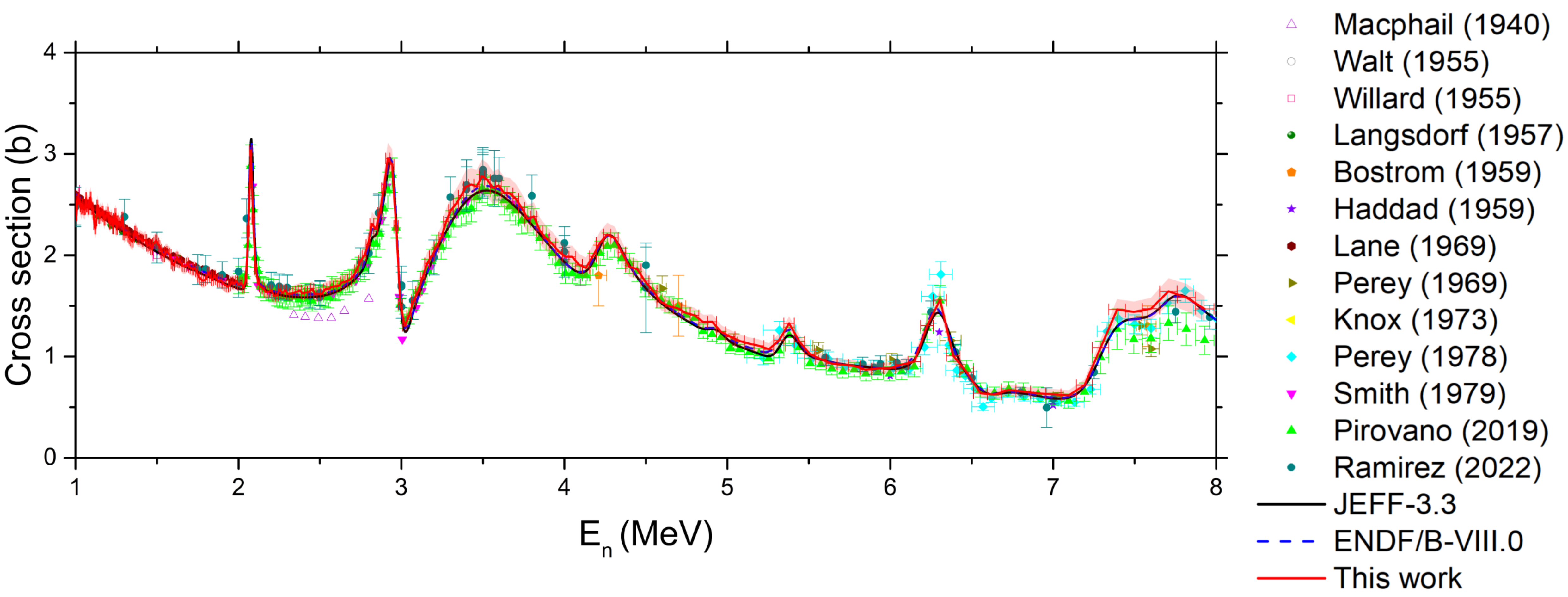
Results of the $^{nat}C(n,n)$



Results of the $^{nat}C(n,n)$ – (EXFOR)



Results of the $^{nat}C(n,n)$ – (Angle-integrated)



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Conclusion

- **Scattering angular distributions** and **neutron elastic scattering cross section** of natural carbon measured in the energy range from **1** to **8 MeV**
- **Total uncertainties** of the cross sections vary from **3%** to **10%**
- **Good agreement** with experimental data available in the literature
- **Interference issues** with evaluated data around **3 MeV** for **backward angles**
- JRC-Geel data will be uploaded to the **EXFOR** library soon!

Back-up

Elastic – Inelastic separation

- Split the neutron t.o.f. spectrum in small intervals of 5 ns each (time resolution of the measurement)
- Knowing the neutron incident energy and the detection angle – via kinematics calculation determine the energy of the neutrons scattered elastically E'_{el} and inelastically E'_{inl}
- Overlaps in the LO distribution of these 2 neutron energies – proper threshold application

$$N_{el}(t.o.f.,\theta) = \frac{1 - F_{msc}(t.o.f.,\theta)}{\varepsilon(E'_{el})|_{L_{THR}} \cdot \Delta\Omega} \int_{L_{THR}} R_{fit}(L, E'_{el}) dL$$

  - $\varepsilon(E'_{el})|_{LTH}$: is the detection efficiency as a function of the detected neutron energy E'_{el}
  - $F_{msc}(t.o.f.,\theta)$: multiple scattering correction factor
  - $R_{fit}(L, E'_{el})$: fitted detector response to the experimental LO spectrum in the interval above the L_{THR}

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Determination of the neutron elastic scattering events

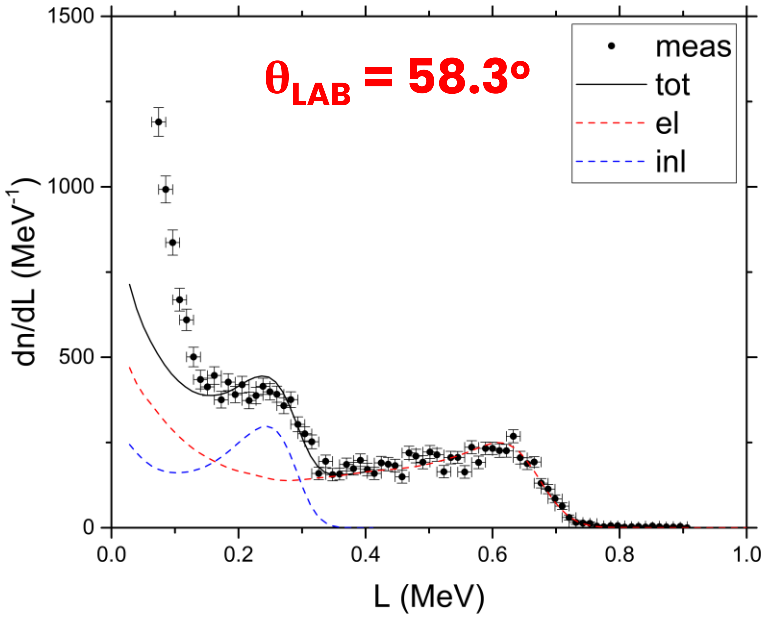
2.Background subtraction

Background contribution from **beam neutrons scattering on air or various materials** around the setup once or twice before reaching the detectors (Sample-in – **Sample-out subtraction**)

3.Elastic-Inelastic separation

Split the neutron t.o.f. spectrum in small intervals of ***5 ns*** each

- Knowing the neutron incident energy and the detection angle – via kinematics calculation determine the energy of the neutrons scattered **elastically** E'_{el} and **inelastically** E'_{inl}
- Overlaps in the LO distribution of these 2 neutron energies – **proper threshold application**



4.Multiple scattering correction

Monte Carlo simulations of the **full detection setup** using the **MCNP6** code and the **PTRAC** file