GELINA
The JRC Neutron Time-of-Flight Facility

Carlos PARADELA DOBARRO, JRC.G.II.6
Nuclear Data and Measurement Standards
European Commission, Joint Research Centre, Geel (BE)

ND2025 16TH NUCLEAR DATA FOR SCIENCE AND TECHNOLOGY CONFERENCE
JUNE 22ND – 27TH | MADRID (SPAIN) | 2025

European Commission

JRC origins

"The Joint Nuclear Research Centre shall include:

…

(c) A bureau of standards specialising in nuclear measurements for isotope analysis and absolute measurements of radiation and neutron absorption, equipped with its own experimental reactor"

Euratom Treaty, Annex V, 1957

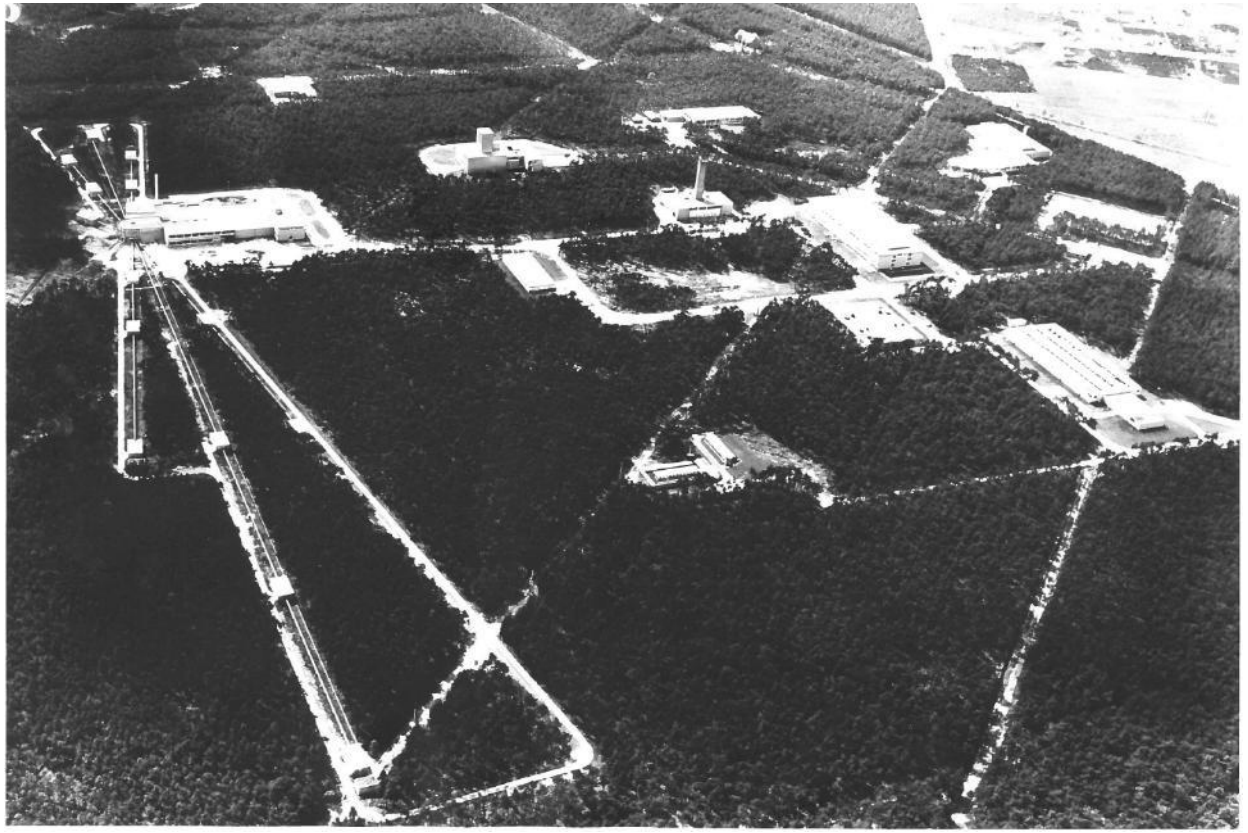
Paul-Henri Spaak and Jean-Charles Snov et d'Oppuers at the signature of the Treaty establishing European Atomic Energy Community (EURATOM) 25.03.1957

Central Bureau for Nuclear Measurements

- Site leased in 1960 for 99 years from SCK-CEN

- A **nuclear** facility; the European Commission is the licence holder

- JNRC became JRC in 1973



CBNM 1965, JRC site in Geel, Belgium

Institute for Refence Materials and Measurements (IRMM)

- **1993:** Renamed “Institute for Reference Materials and Measurements” (IRMM)

- Increasing number of non-nuclear activities

IRMM site in 2013

Joint Research Centre (JRC-Geel)

- **2016:** New organisation: No more Institutes, but sites

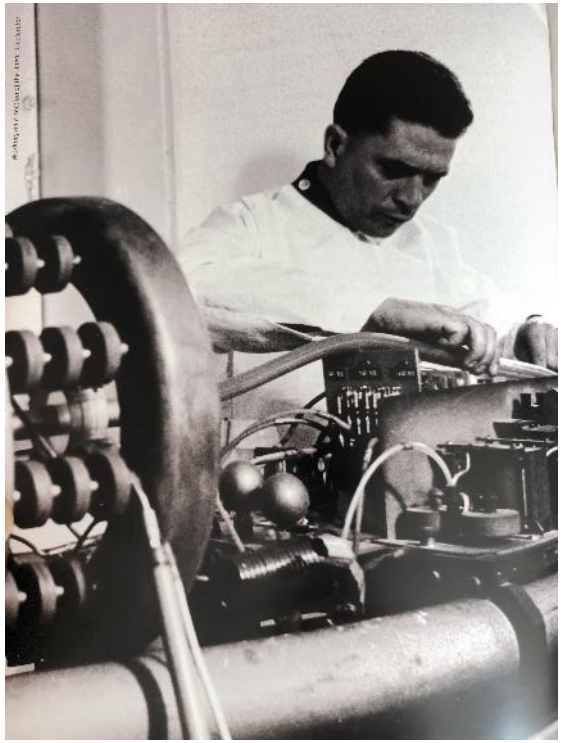
- **2016-2020:** VdG became MONNET (3.5 MV Tandem)

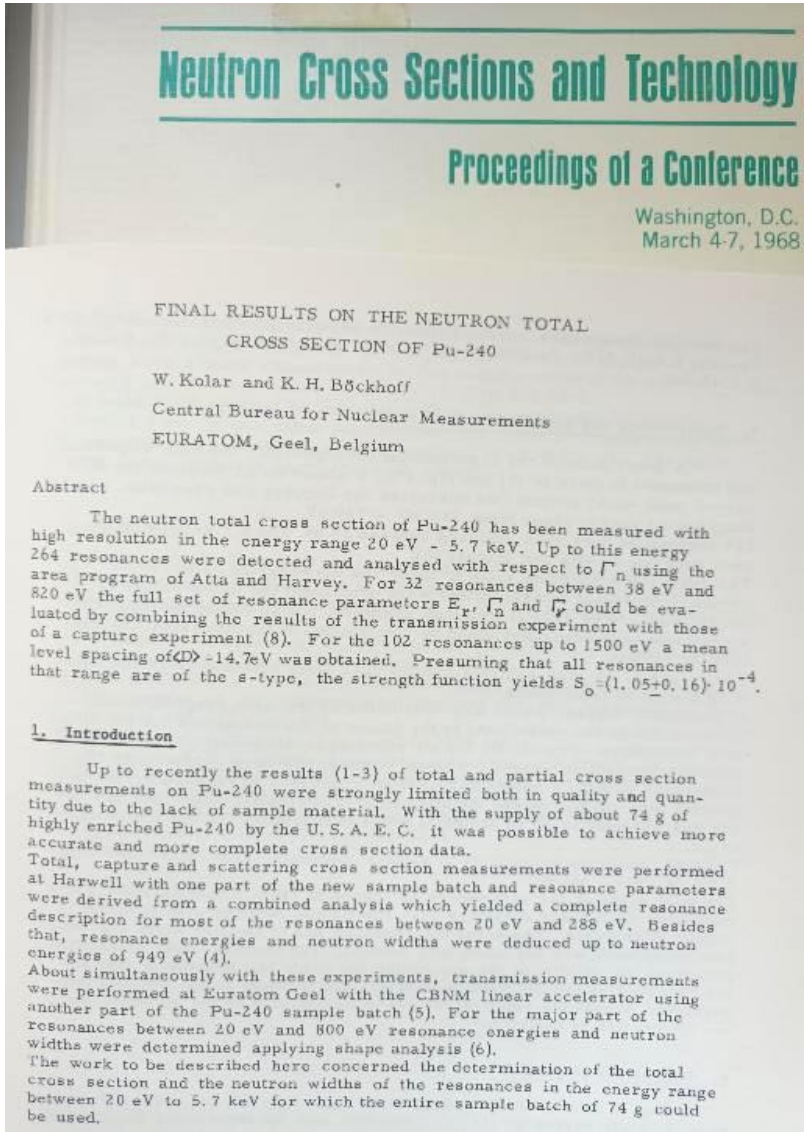
  #163 C.L. Fontana S2 Tue M1

GELINA in 2018, JRC-Geel site

The linear accelerator

- 1965: 70 MeV Linear Accelerator
- 1970's: Upgrade to 150 MeV





Neutron Cross Sections and Technology

Proceedings of a Conference

Washington, D.C.
March 4-7, 1968

FINAL RESULTS ON THE NEUTRON TOTAL CROSS SECTION OF Pu-240

W. Kolar and K. H. Böckhoff
Central Bureau for Nuclear Measurements
EURATOM, Geel, Belgium

Abstract

The neutron total cross section of Pu-240 has been measured with high resolution in the energy range 20 eV - 5.7 keV. Up to this energy 264 resonances were detected and analysed with respect to Γ_n using the area program of Atta and Harvey. For 32 resonances between 38 eV and 820 eV the full set of resonance parameters E_r, Γ_n and Γ_γ could be evaluated by combining the results of the transmission experiment with those of a capture experiment (8). For the 102 resonances up to 1500 eV a mean level spacing of $\langle D \rangle = 14.7$ eV was obtained. Presuming that all resonances in that range are of the s-type, the strength function yields $S_o = (1.05 \pm 0.16) \cdot 10^{-4}$.

1. Introduction

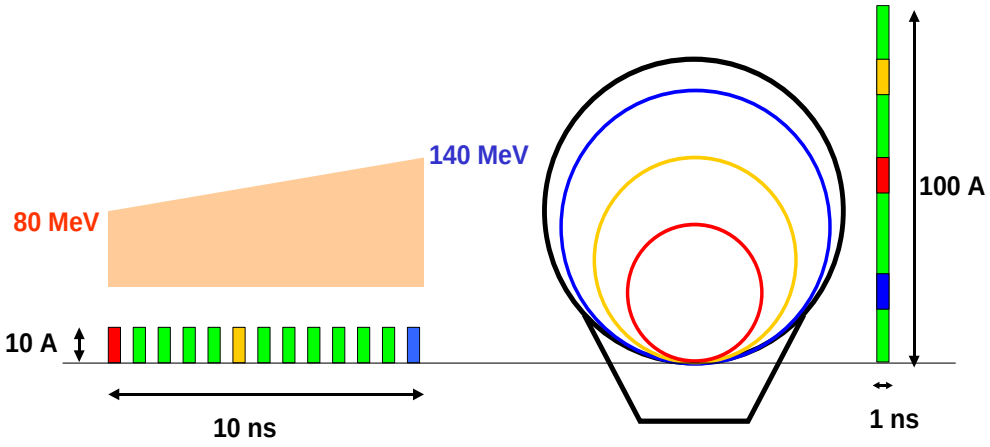
Up to recently the results (1-3) of total and partial cross section measurements on Pu-240 were strongly limited both in quality and quantity due to the lack of sample material. With the supply of about 74 g of highly enriched Pu-240 by the U. S. A. E. C. it was possible to achieve more accurate and more complete cross section data.
Total, capture and scattering cross section measurements were performed at Harwell with one part of the new sample batch and resonance parameters were derived from a combined analysis which yielded a complete resonance description for most of the resonances between 20 eV and 288 eV. Besides that, resonance energies and neutron widths were deduced up to neutron energies of 949 eV (4).
About simultaneously with these experiments, transmission measurements were performed at Euratom Geel with the CBNM linear accelerator using another part of the Pu-240 sample batch (5). For the major part of the resonances between 20 eV and 800 eV resonance energies and neutron widths were determined applying shape analysis (6).
The work to be described here concerned the determination of the total cross section and the neutron widths of the resonances in the energy range between 20 eV to 5.7 keV for which the entire sample batch of 74 g could be used.

First experiment: transmission on Pu-240

European Commission

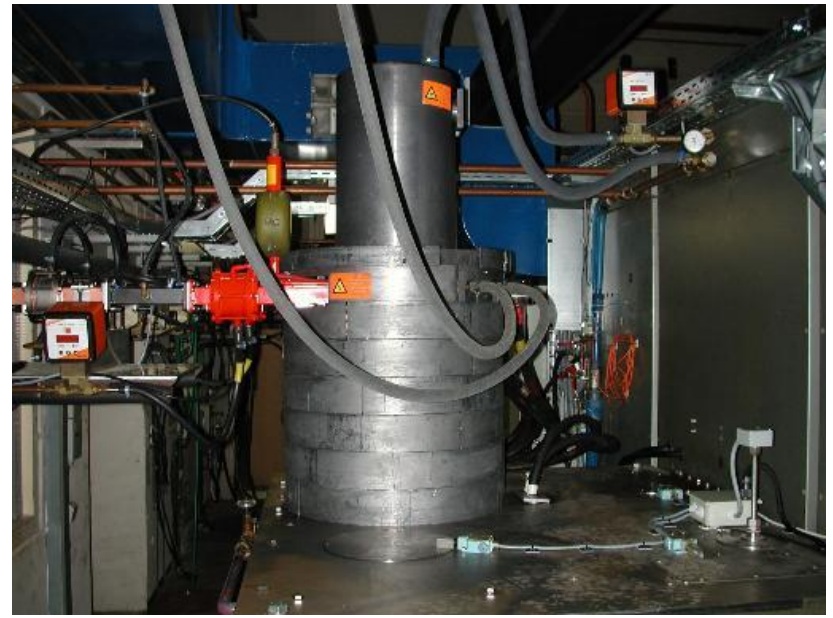
The linear accelerator

- 1965: 70 MeV Linear Accelerator
- 1970's: Upgrade to 150 MeV
- **1983: Pulse compression magnet**



The linear accelerator

- 1965: 70 MeV Linear Accelerator
- 1970's: Upgrade to 150 MeV
- 1983: Pulse compression magnet
- **1990's: new types of klystrons, modulators, wave guides…**



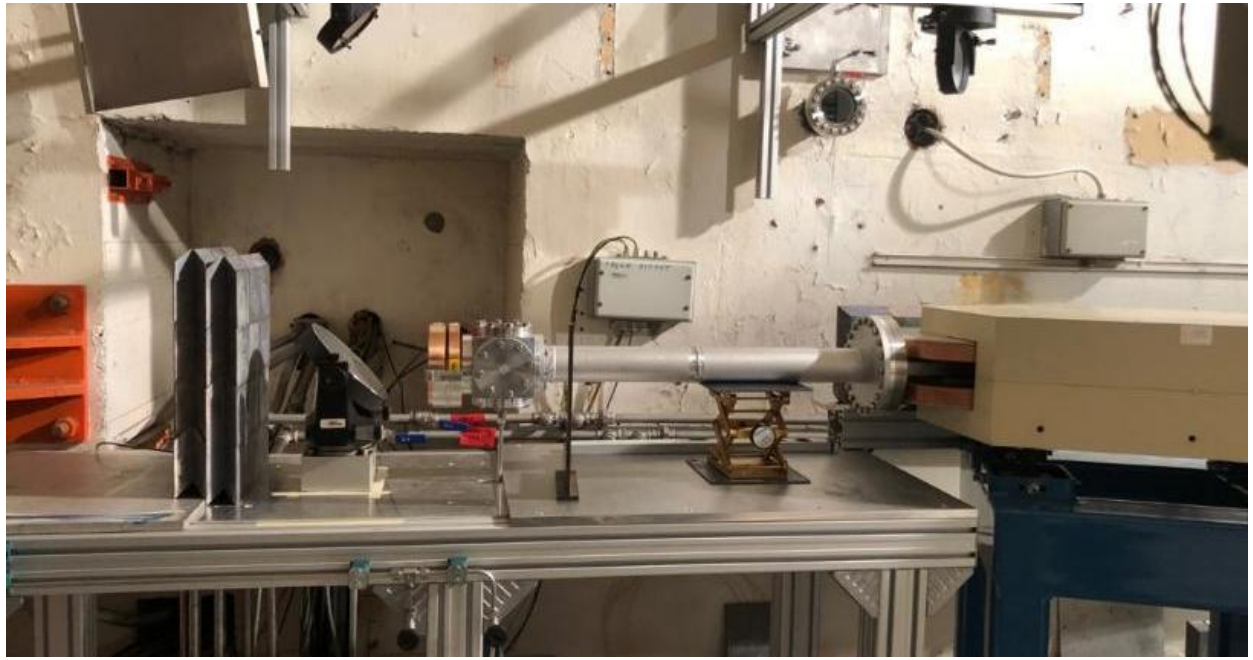
The linear accelerator

- 1965: 70 MeV Linear Accelerator
- 1970's: Upgrade to 150 MeV
- 1983: Pulse compression magnet (1 ns)
- 1990's: new types of klystrons, modulators, wave guides…
- **2000's: computer-controlled beam handling, target replacement**

The linear accelerator

- 1970’s: Upgrade to 150 MeV
- 1983: Pulse compression magnet
- 1990’s: new types of klystrons, modulators, wave guides…
- 2000’s: computer-controlled beam handling, target replacement
- **2010’s: renovation of FP cabins**

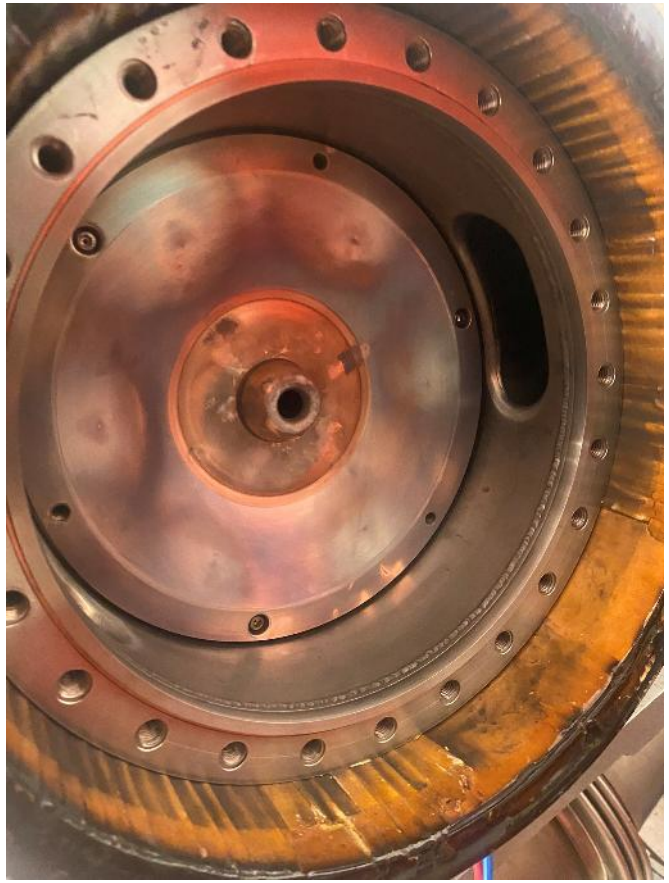
New Beam Line (2019-2021)



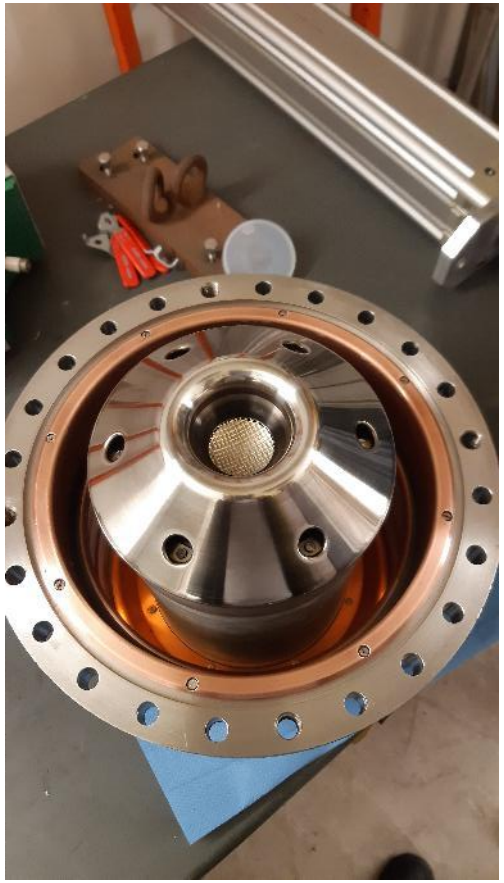
- Study of photon-induced reaction of medical interest (radioisotope production)
- #180, A. Tsinganis S1 Wed A1

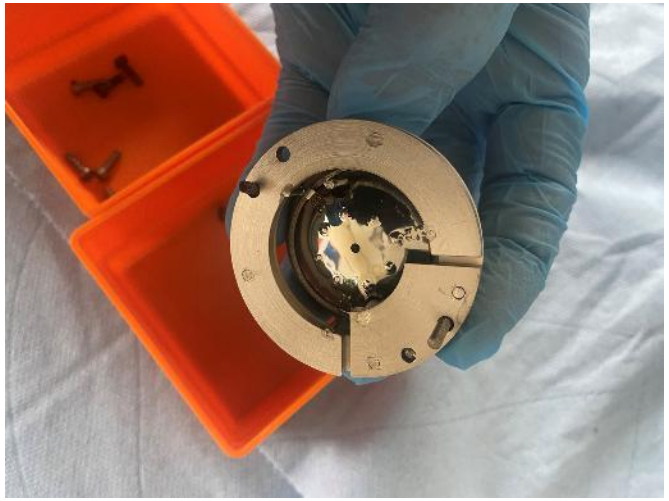
Cathode damage (2022-2023)

Injection (anode side) July 2022



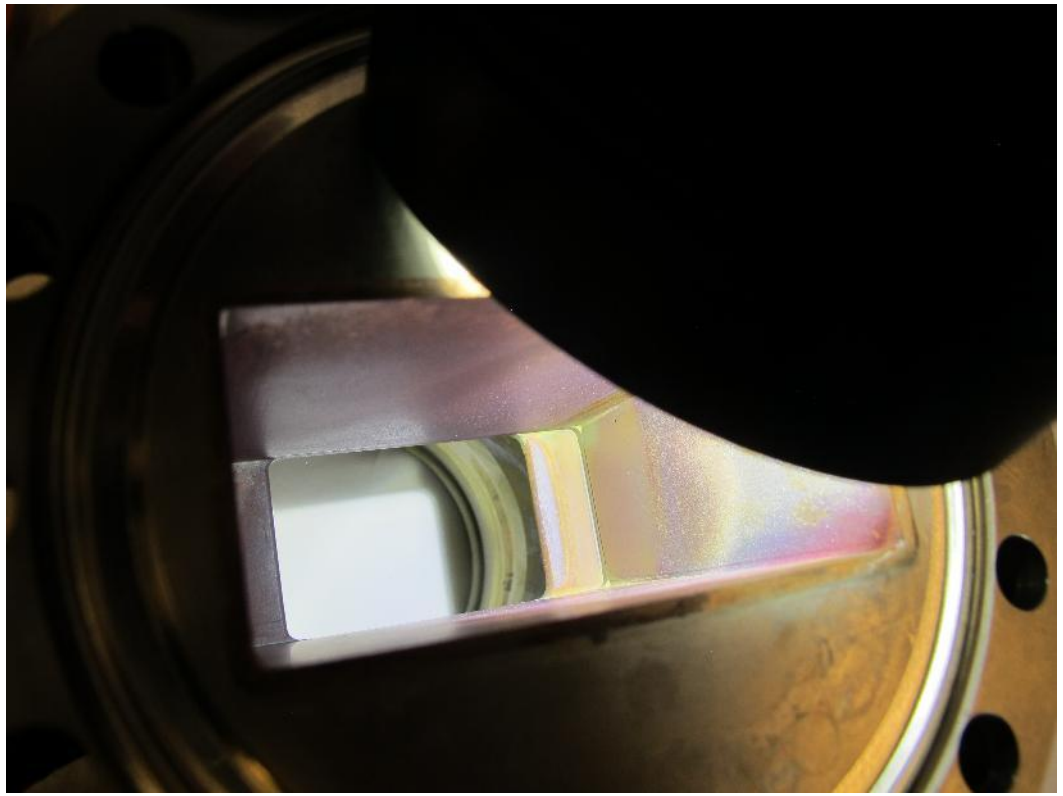
Injection (cathode side) May 2023





Long shutdown (September 2023- March 2025)

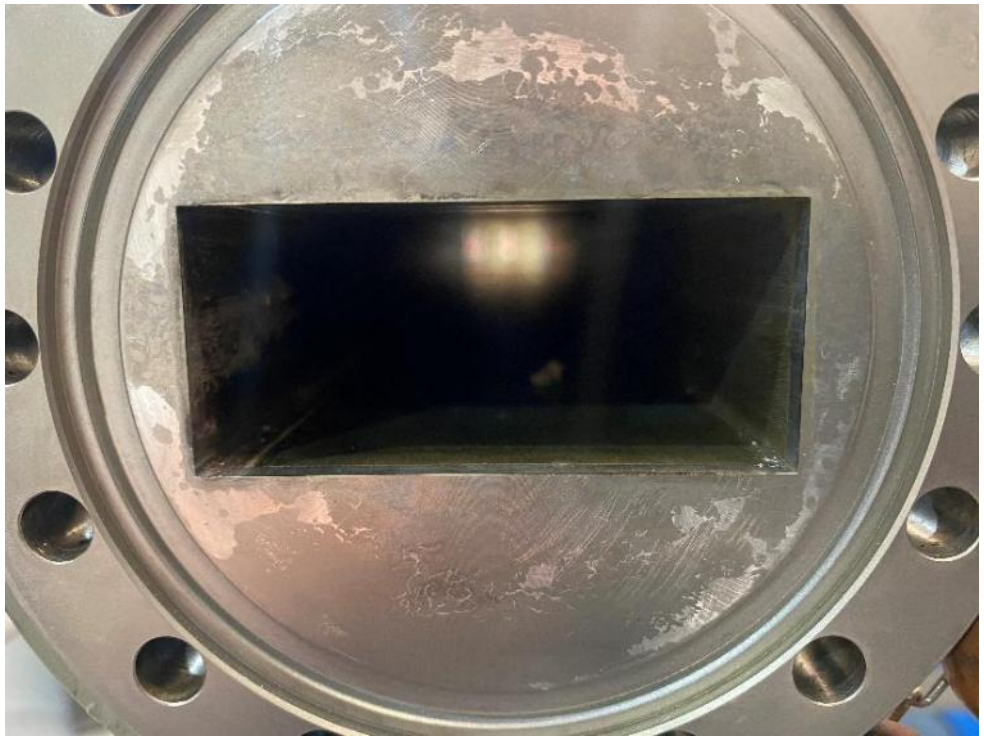
RF window October 2023



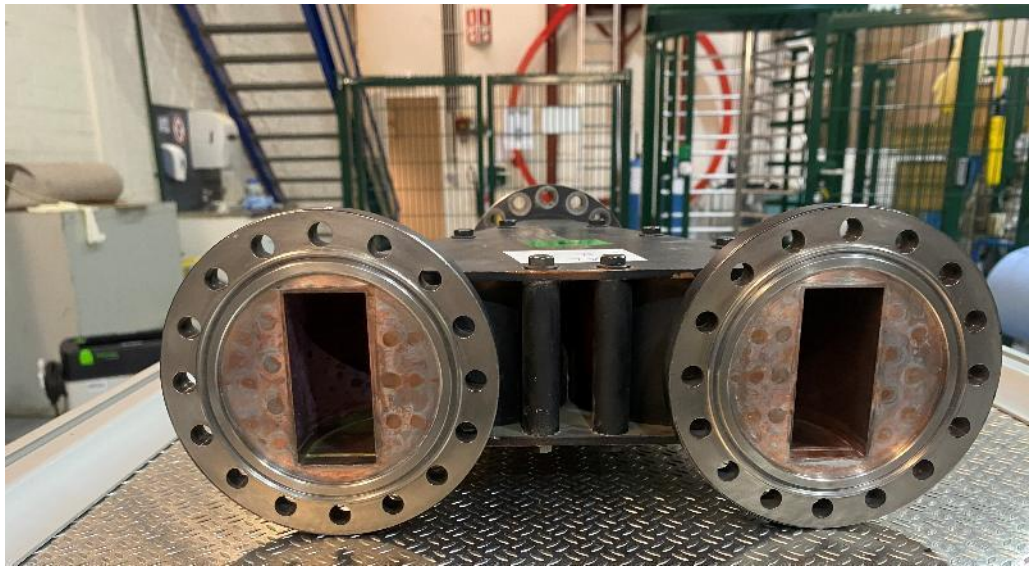
Broken RF window October 2023

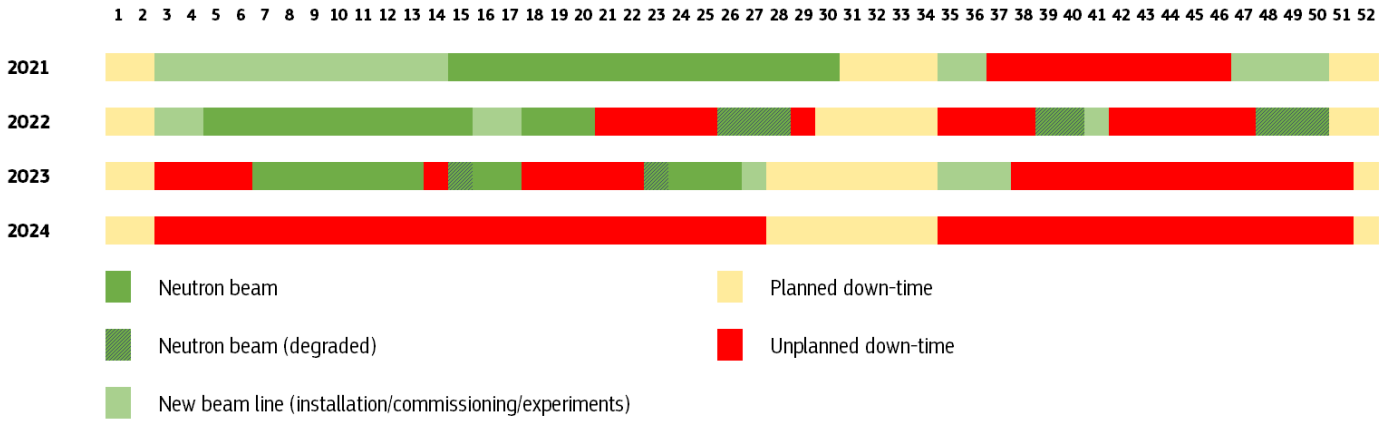
Long shutdown (September 2023- March 2025)

Cleaning of



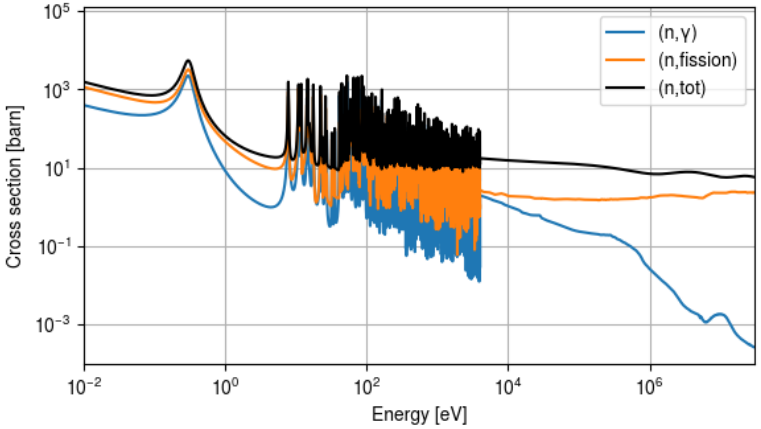
Broken RF window October 2023

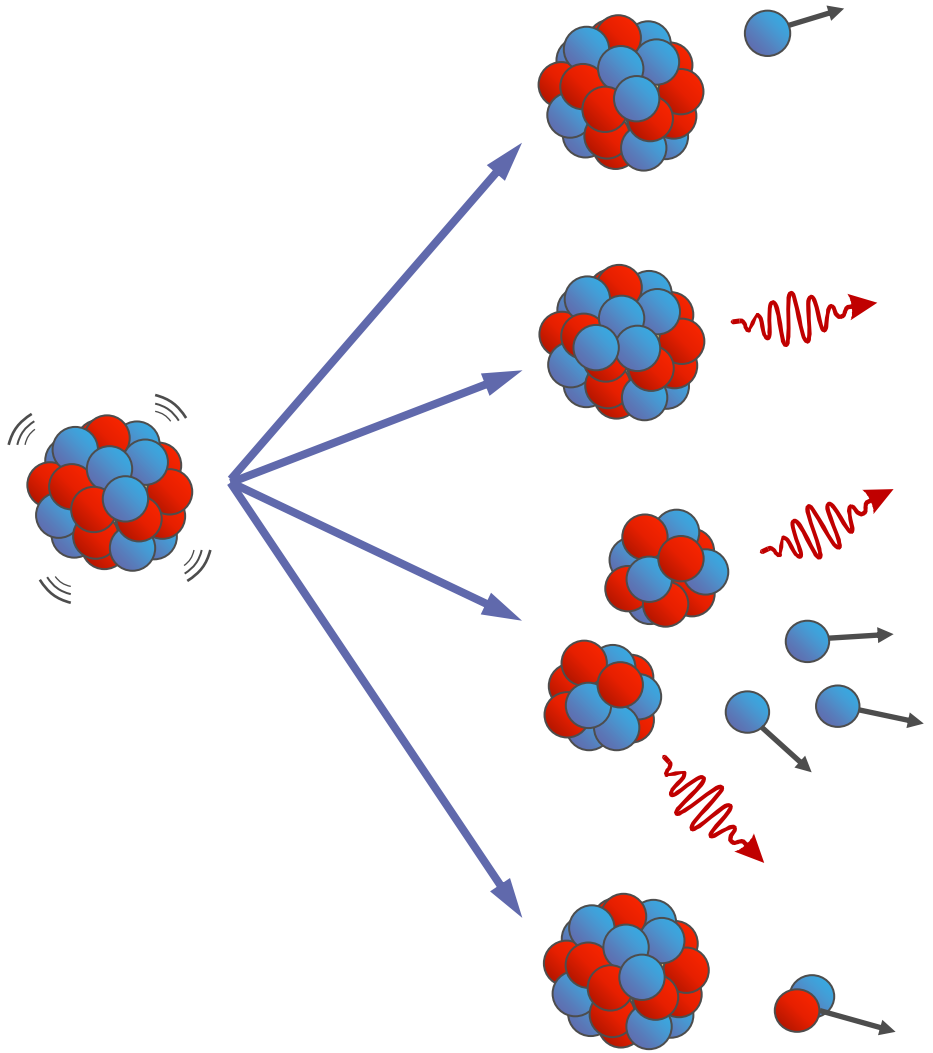




Neutron-induced reactions

^{239}Pu neutron cross-sections





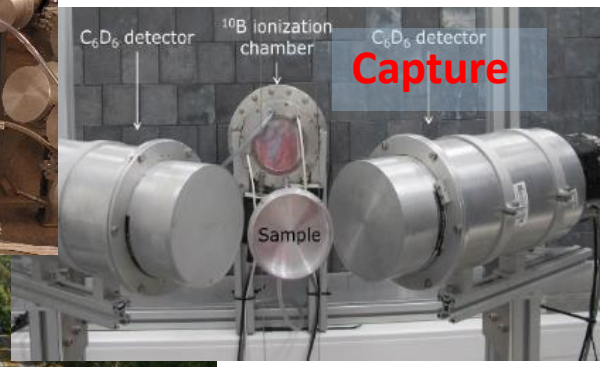
Scattering (n,n) (n,n'γ)

Capture (n,γ)

Fission (n,f)

Other reactions
(n,p), (n,d), (n,α), ...

GELINA: In-house experimental set-ups



- Transmission (n,tot)
  FP13-10 m, FP12-30 m, FP4-50 m
- Capture (n,γ)
  FP5-10 m, FP15-30m, FP14-60 m
- Fission (n,f)
  FP2-10 m, FP17-8 m (SCINTIA)
- Elastic, in-elastic scattering (n,n),(n,n'γ)
  FP1-30 m (ELISA)
- In-elastic scattering (n,n'γ)
  FP16-30 m, FP3-100 m (GAINS)
- Target hall

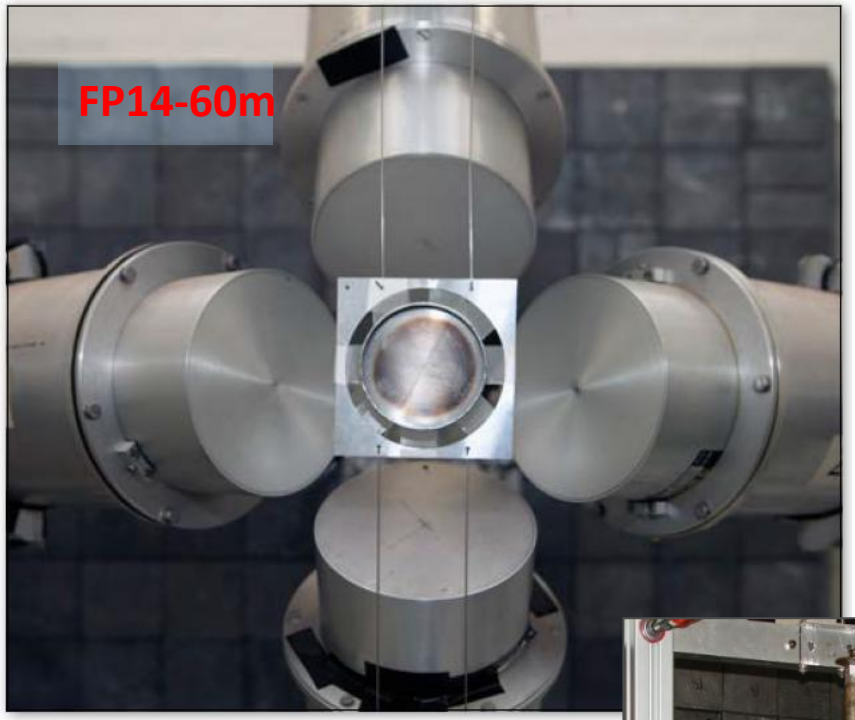
European Commission

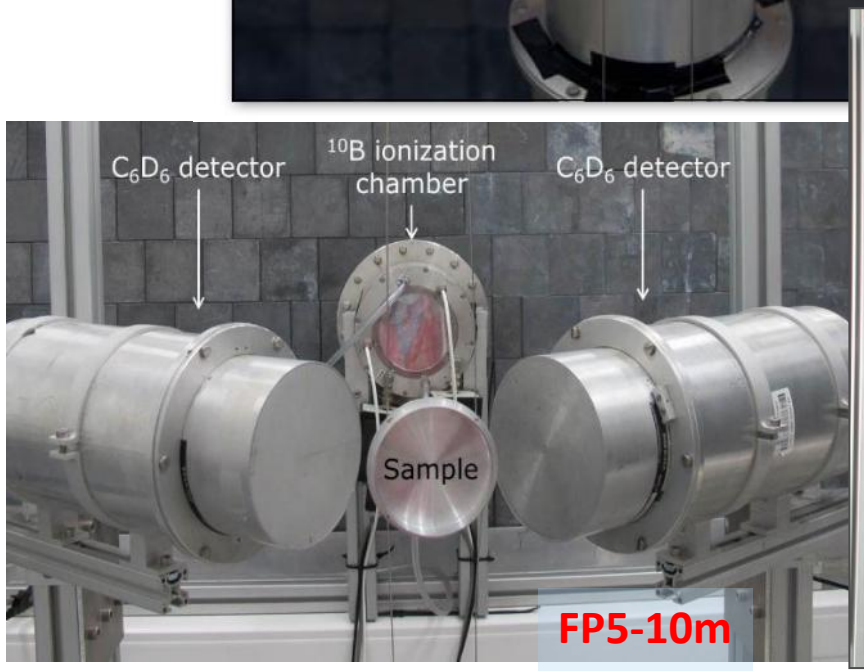
GELINA – Neutron capture set-ups

- Total energy detection principle
  - C_6D_6 liquid scintillators
    (Boron free quartz window!)
  - 125°
  - Pulse Height Weighting Technique
- Fluence rate measurements (IC)
  - **$^{10}B(n,\alpha)$** or $^{235}U(n,f)$
- Supporting DoE NCSP: Ca, Ce, V, La, Zr…

#486 K. Guber S6 Thu M2

- NRCA applications: cultural heritage, trace elements quantification (Ag content in Bi rom Venus-F reactor, SCK CoA)





GELINA – transmission station at 50 m

- Direct relation between transmission (T_{exp}) and total cross section (σ_{tot})
- Experimental program on structural materials: Pb, Fe, Cu

#626, P. Romojaro S1 Tue M1

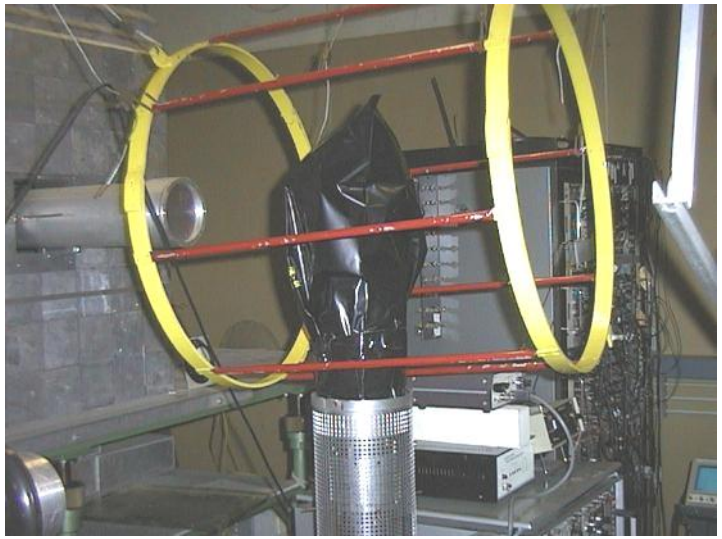
#216, G. Gkatis, Poster Tue M1

#524, M. Diakaki, S1 Thu M1

- Complementing capture data for DoE-NCSP and CERN-n_TOF

FP4-25m (2011)

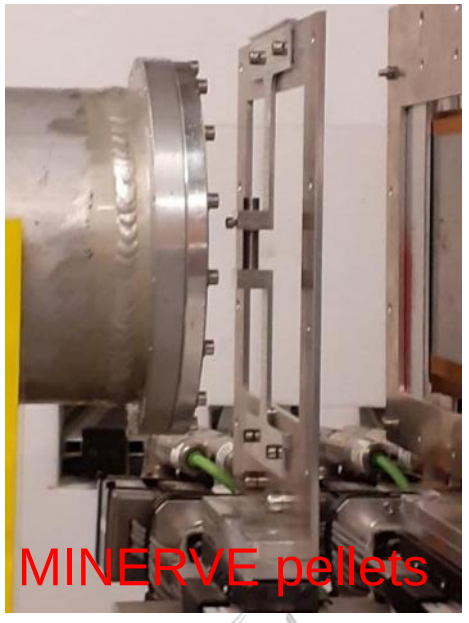
FP4-50m



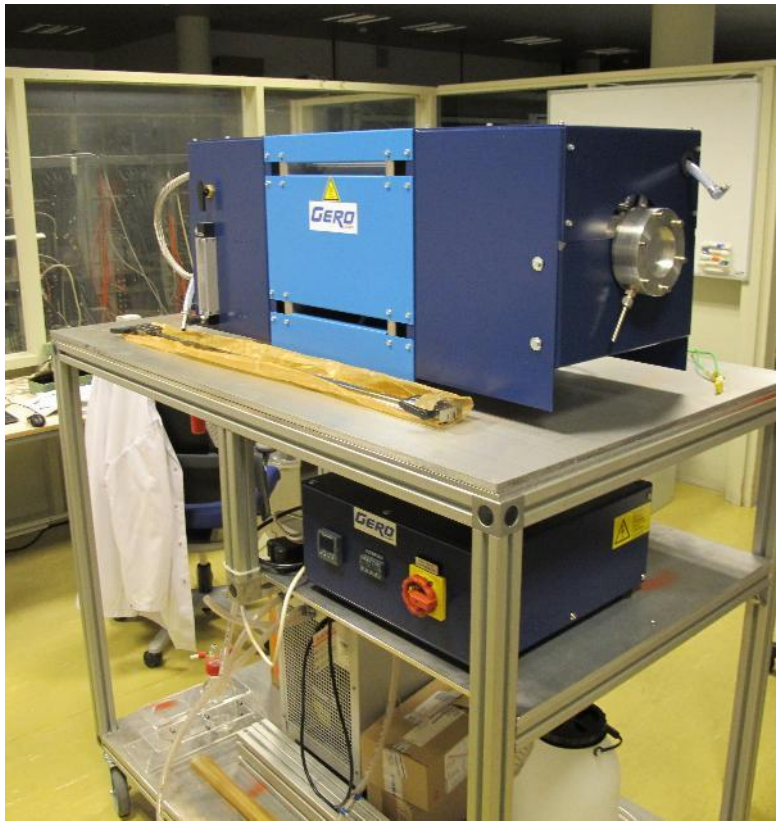
GELINA – transmission stations at 10 m

- Built in 2013 for validating NRTA and applications
- Transmission on enriched Mo n_TOF samples

#626, R. Mucciola S4 Tue A1



GELINA – Transmission at 30 m



New transmission station equipped with a furnace for **high temperature (up to 1000°C) cross section measurements** to study the **Doppler effect**

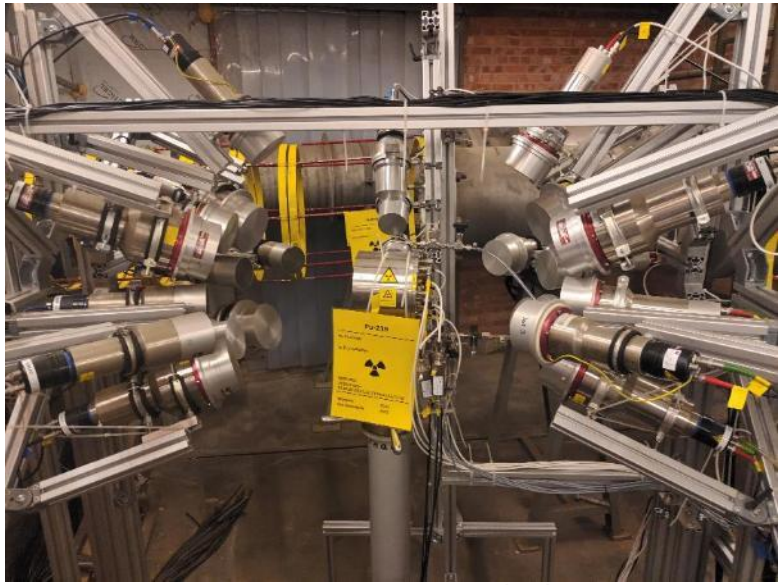
European Commission

Scintia (Neutron detector array)

Fission studies for model validation

#466, O. Serot, S1 Wed M1

- Multi-layer Fission Chamber loaded with ^{239}Pu targets
- Prompt fission neutrons
  - 22 x Liquid organic **Scintillators**
  - Energy : time-of-flight
- Prompt fission gammas
  - **LaBr** detectors
- Digital DAQ

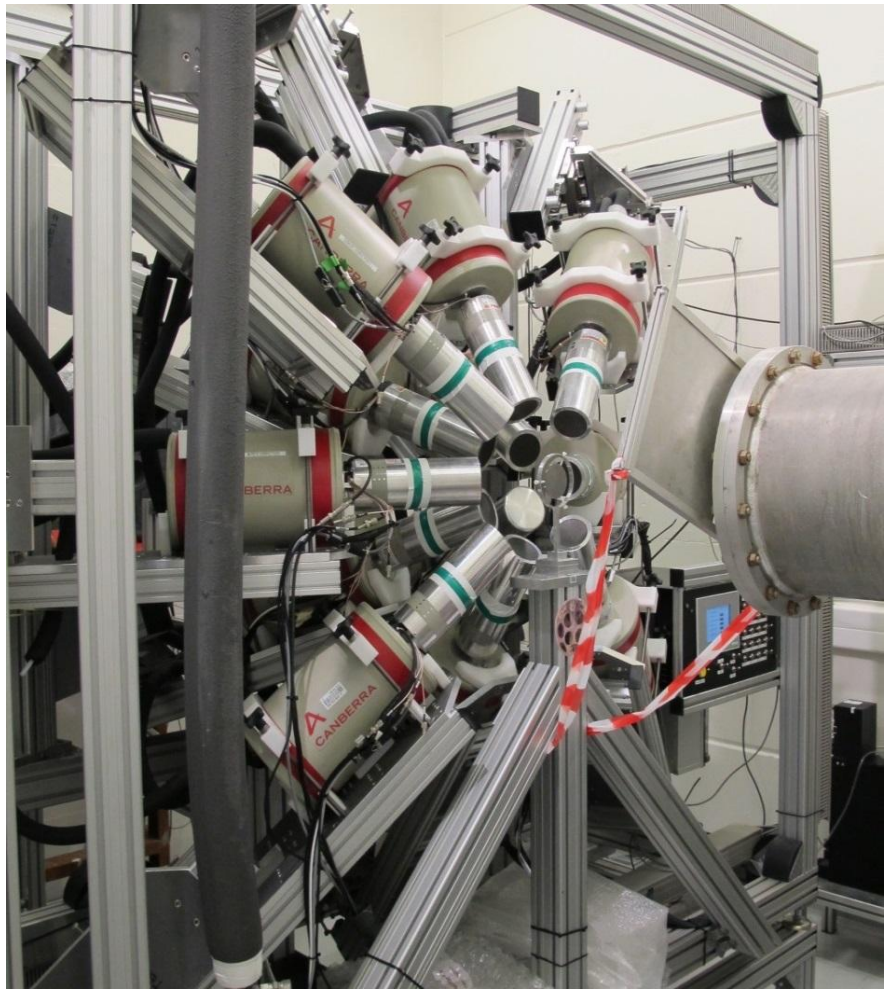


GAINS (**G**amma **A**rray for **I**nelastic **N**eutron **S**cattering)

GAINS history

- 2 HPGe detectors at 110º and 150º
- ^{235}U fission chamber for flux measurement
- FP3-200 m flight path moved to FP3-100m in 2015 (8 ns FWHM resolution)
- Conventional electronics for all detectors moved to DC 440 Acqiris digitizers (12 bits and 400 MHz) in 2004.

GAINS (**G**amma **A**rray for **I**nelastic **N**eutron **S**cattering)



FP3-100m (2021)

Neutron-inelastic scattering set-up
gamma-sensitive detectors

- 12 **HPGe** detectors at 100 m (*2 LaBr)
- New acquisition system

  #226, M. Kavatsyuk S7 Tue M2

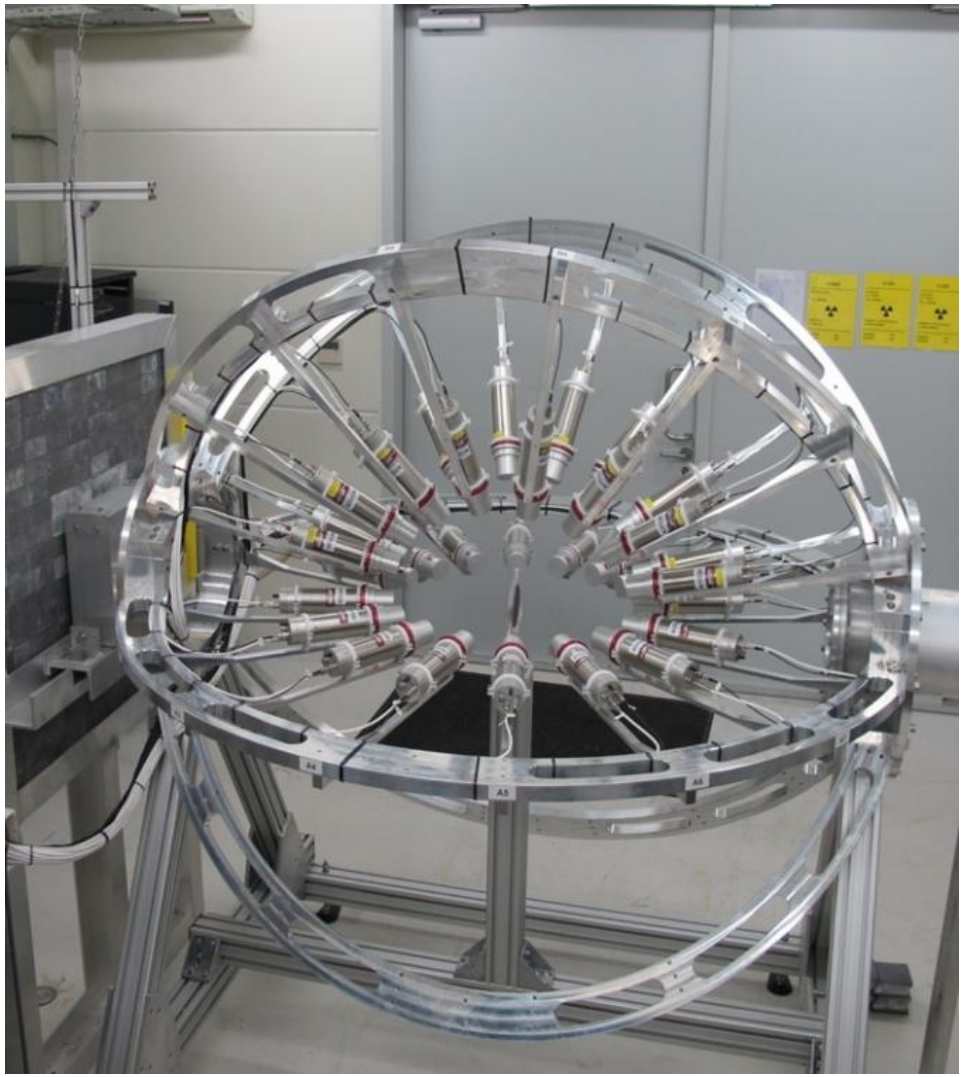
  #219 A. Farzanehpoor S7 Wed M1

- ^{7}Li, ^{12}C, **^{14}N,** ^{16}O, **^{19}F** ^{23}Na, ^{24}Mg, ^{28}Si, **^{40}Ca,** ^{nat}Ti, ^{nat}Mo, ^{52}Cr, ^{54}Fe, **^{56}Fe**, ^{57}Fe, ^{58}Ni, ^{60}Ni, ^{76}Ge, ^{nat}Zr, ^{206,207,208}Pb, ^{209}Bi

  #178, A. Oprea; #136, M. Boromiza; #114 S1 Thu M1

  #48, A. Negret; #95, A. Coman S1 Thu M2

ELISA (**EL**astic and **I**nelastic **S**cattering **A**rray)

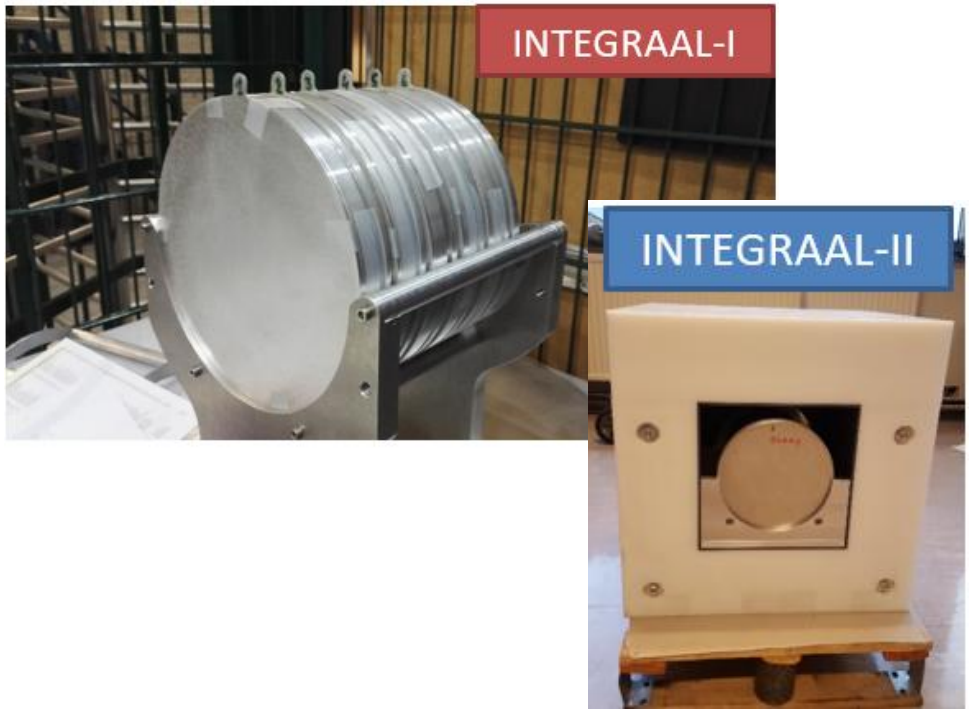


Neutron-scattering set-up
➔ neutron-sensitive detectors

- 32 (4x8) **liquid organic scintillators**
  - 16 EJ301 (NE213)
  - 16 EJ315 (C6D6)
- **Different signal shape for n and γ**
- Very fast signals-> Good timing
- Neutron flux monitoring with a ^{235}U fission chamber
- C, Fe, Na

#215, G. Gkatis, S1 Tue M2
#524, M. Diakaki, S1 Thu M1

Target Hall experiments



- Purpose of INTEGRAAL: investigation of $^{238}U(n,n')$ reaction through integral transmission experiment
- INTEGRAAL-II: added shielding for reducing the neutron room return

Working with partners through JRC Open Access - EUFRAT

- The JRC provides access to its nuclear facilities to EU Member States and countries associated to the EURATOM Research & Training Programme
- Access is allocated on scientific merit via a call for proposals, following the recommendations of a User Selection Committee
- Open access to GELINA, MONNET, RADMET and HADES
- Access to nuclear research facilities granted free of charge
- Financial support to users for short- and long-term visits


User Selection Committee (USC) meeting 2019

https://ec.europa.eu/jrc/en/research-facility/open-access

European Commission

Education & Training

European Commission

Conclusions

- GELINA 60th anniversary means ageing facility
- Staff reduction: Peter's retirement

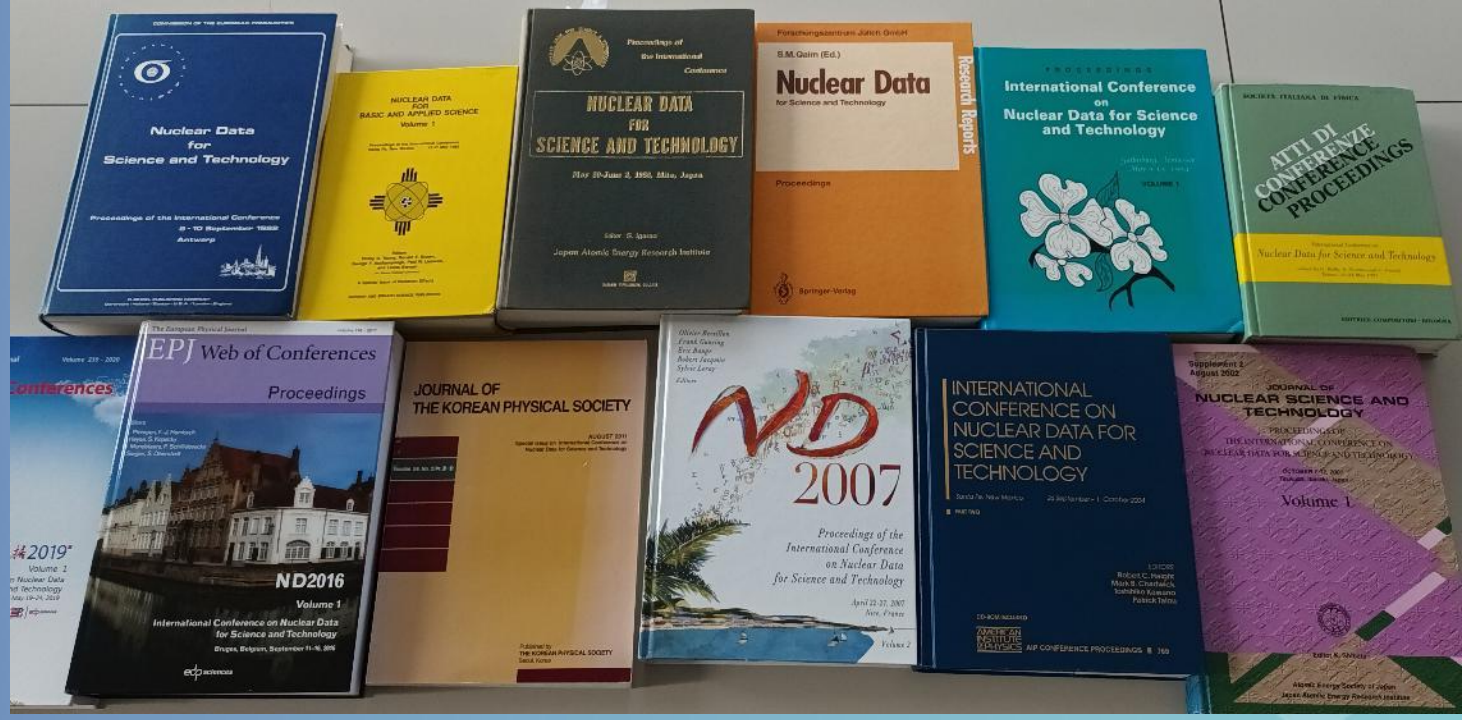
Challenging but promising future…

- Enthusiastic young team and experimented technical support
- High interest to use GELINA: 9 new proposals in last EUFRAT call
- Setup upgrades and ongoing R&D in new applications: industrial NRTA, NRTI

We are ready to continue running for some time!!

New neutron target

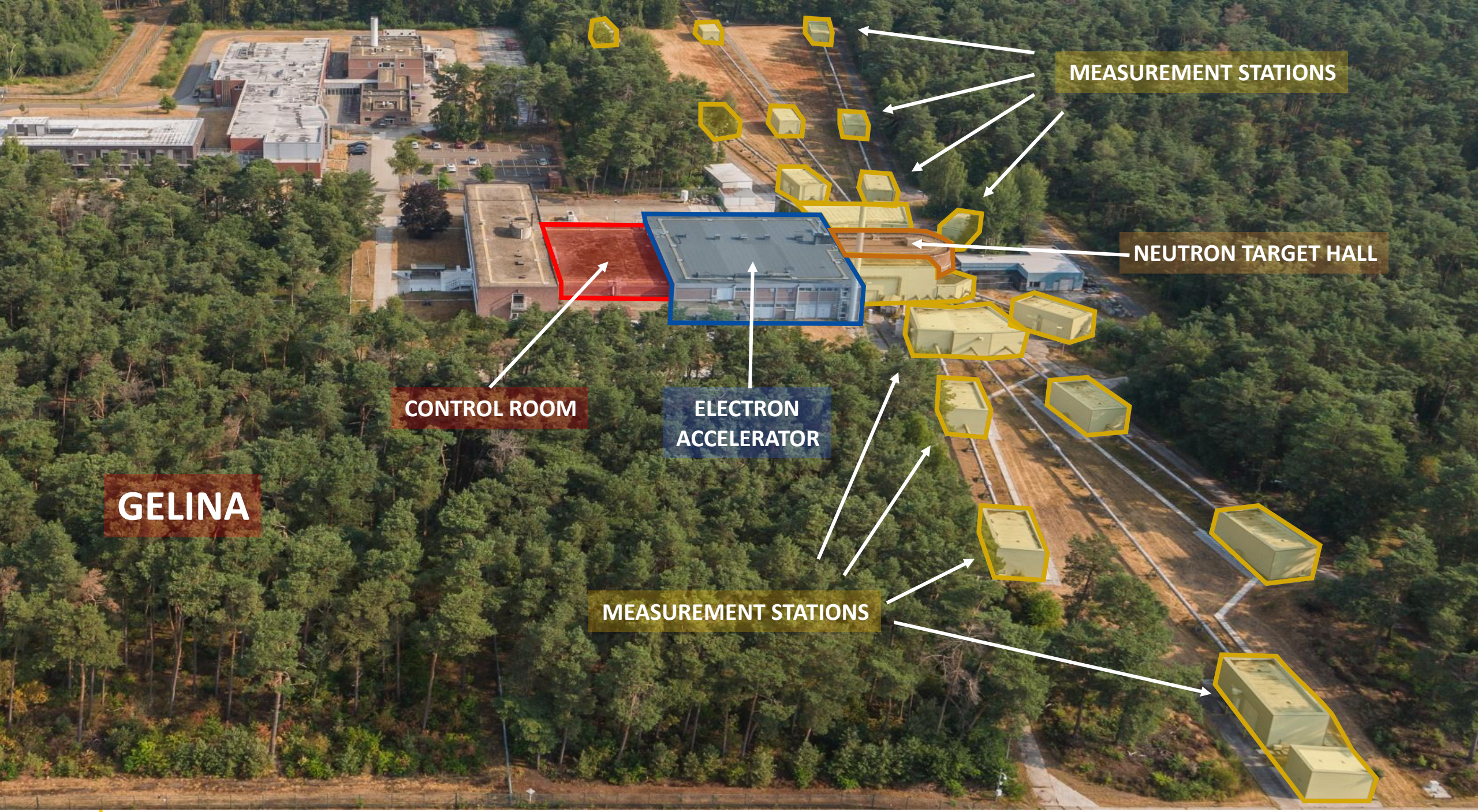
Thank you



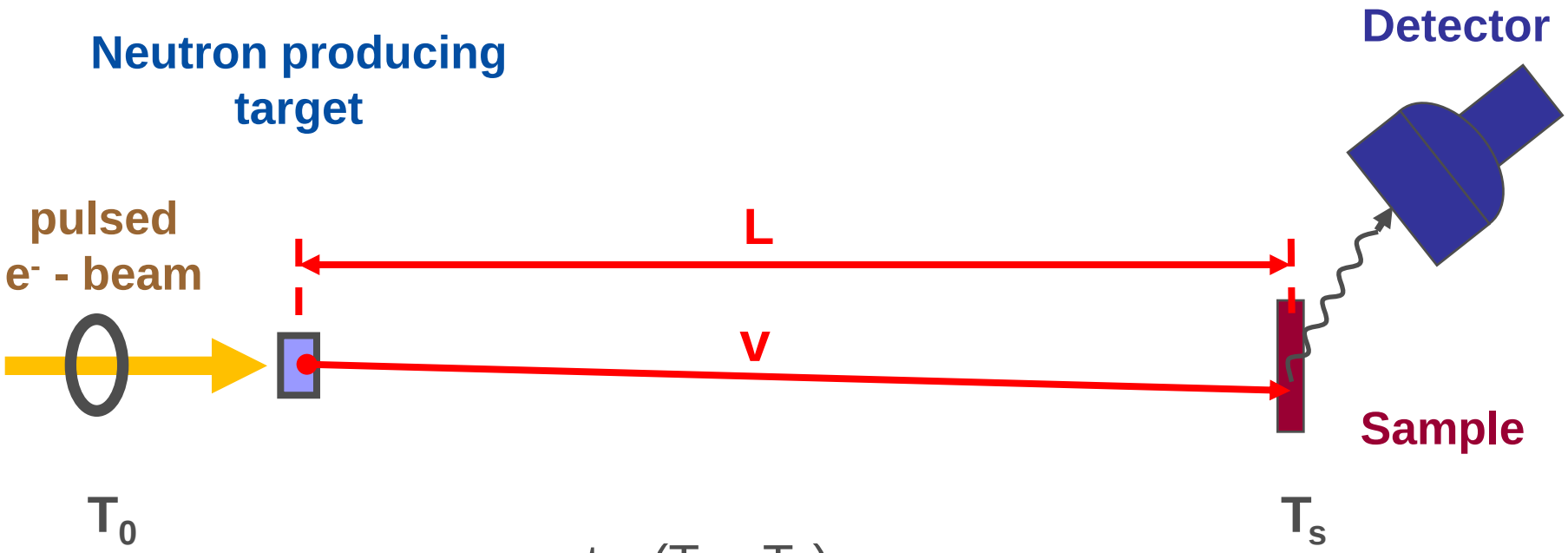
EU Science Hub

Joint-research-centre.ec.europa.eu

European Commission


MEASUREMENT STATIONS
NEUTRON TARGET HALL
CONTROL ROOM
ELECTRON ACCELERATOR
GELINA
MEASUREMENT STATIONS

GELINA – Neutron Time-of-flight



$$t \approx (T_s - T_0)$$

$$v = \frac{L}{t} \quad \Rightarrow E \cong \frac{1}{2} m v^2$$

GELINA - Cross section measurements

Total cross section

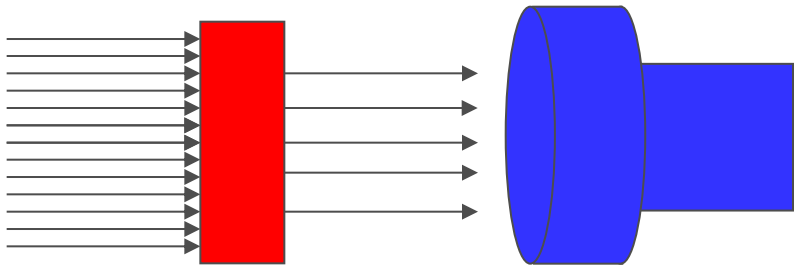
$$T \cong e^{-\,n\,\sigma_{tot}}$$

Reaction cross section

$$Y_\gamma \approx (1 - e^{-\,n\,\sigma_{tot}})\frac{\sigma_\gamma}{\sigma_{tot}}$$

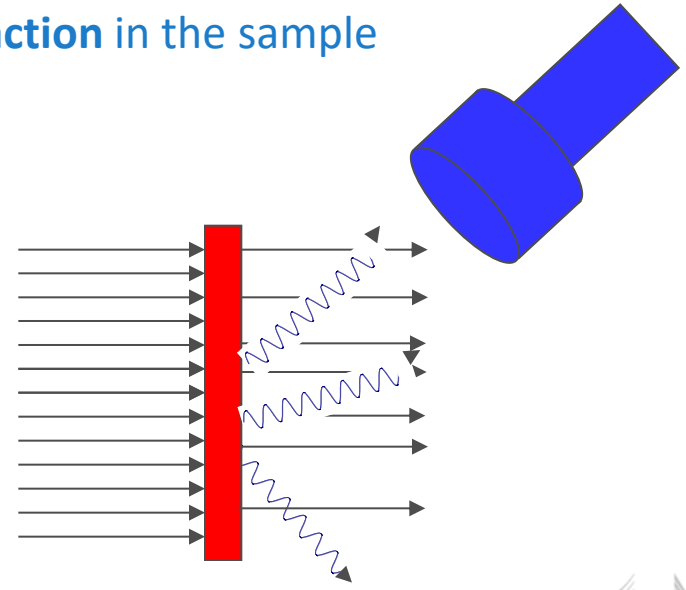
T = transmission

Fraction of the neutron beam traversing the sample **without any interaction**



Y_r = reaction yield

Fraction of the neutron beam creating a **(n,γ) reaction** in the sample



GELINA - Cross section measurements

Total cross section

$$T \cong e^{-n\sigma_{tot}}$$

Reaction cross section

$$Y_\gamma \approx (1 - e^{-n\,\sigma_{tot}})\frac{\sigma_\gamma}{\sigma_{tot}}$$

Well-characterised samples

n: areal density (total number of atoms per unit area) is well-known

⇓

accurate cross-sections can be determined