Fostering collaborations at neutron data facilities in Europe: EUFRAT and related projects

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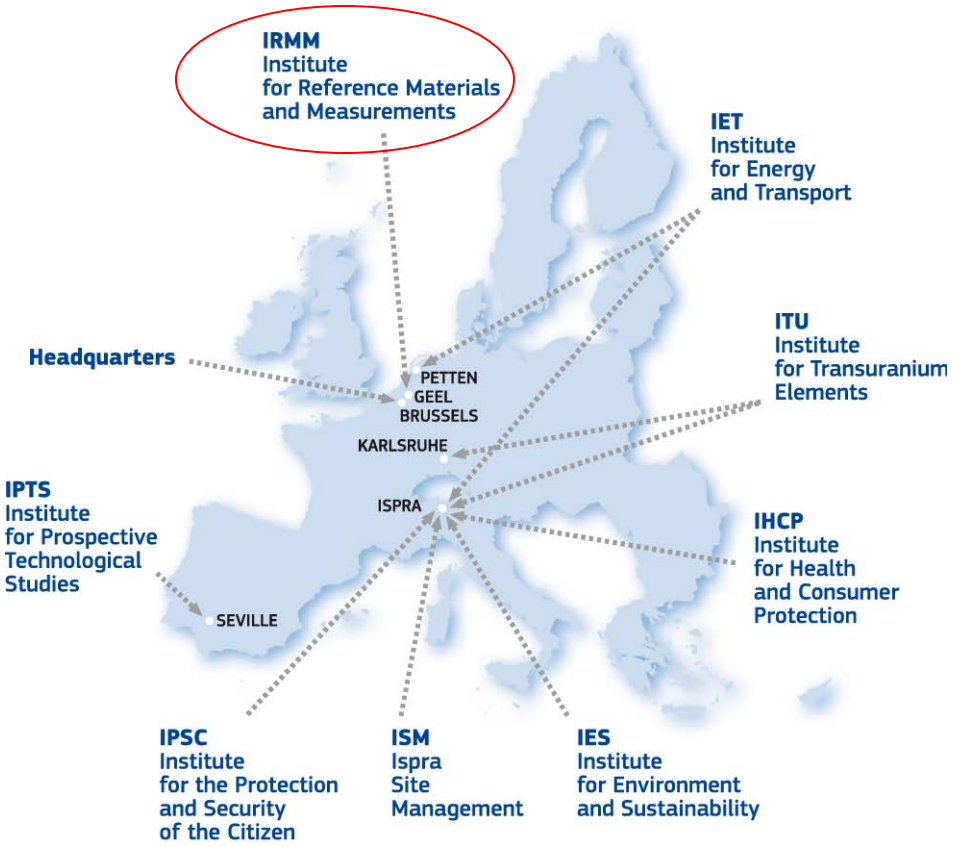
EC-JRC-IRMM (Geel, Belgium)

The Joint Research Centre (JRC) of the European Commission



- **European Commission's in-house science service**
- **Supporting EU policies with independent, evidence-based scientific and technical support**
- **3000 staff**
- **7 institutes in 6 locations**

Nuclear Safety and Security

- **Neutron Data measurements for nuclear energy applications**
- **Basic research in fission**

- Radionuclide metrology
- Radioactivity in the environment

- Metrological tools for safeguards

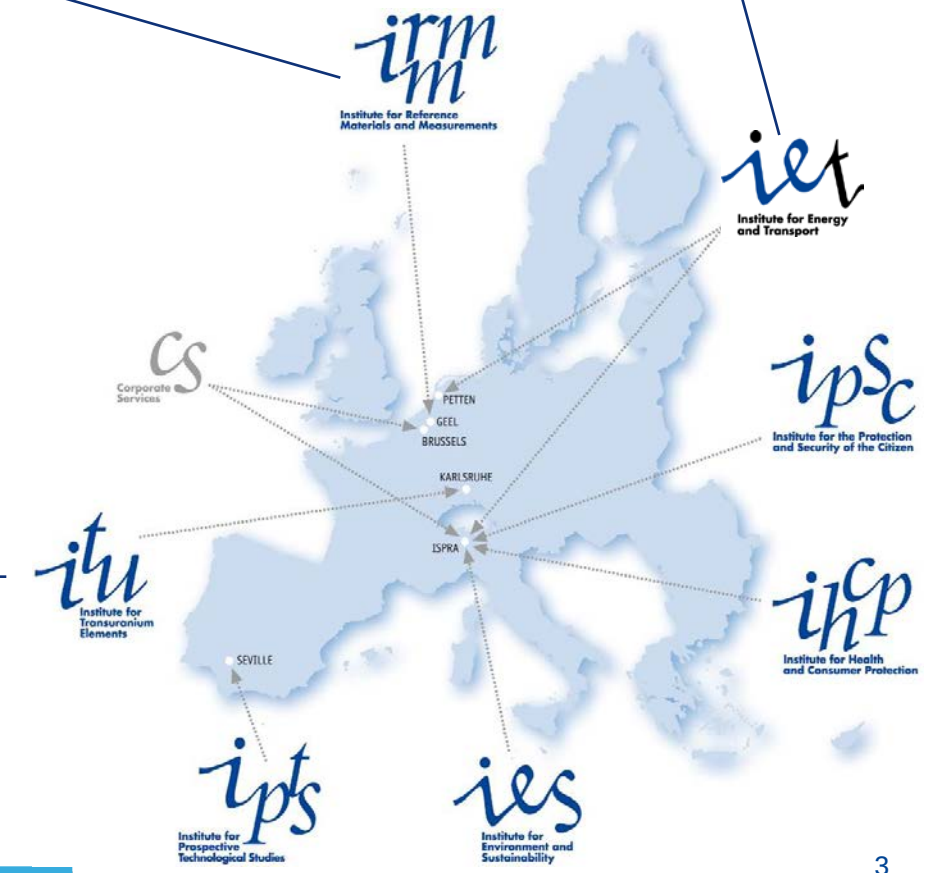
- Safety of nuclear installations
- Advanced nuclear energy systems
- Operational experience feedback

- Fundamental properties of Actinides & Nuclear Materials

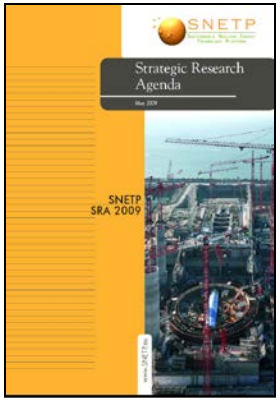
- Nuclear fuel safety
- Safety of nuclear fuel cycle
- Nuclear waste management & decommissioning
- Radioactivity in the environment

- Nuclear safeguards
- Absence of undeclared activities
- Non-proliferation
- Combating illicit trafficking

- Alpha-immunotherapy



Role of nuclear data for nuclear energy applications



A common European approach to the safety evaluation of present-day and innovative reactor systems and of the fuel cycle

- Safety assessments: very detailed simulations of reactor behaviour in **nominal, incidental and accidental conditions**
- Precise simulation of **all relevant nuclear reactions**
- Accuracy of these calculations is largely determined by the **accuracy of the nuclear data**
  - Often data sets are not accurate enough or discrepant
  - Evaluated data perform not always well
  - Missing covariance data

How well can we calculate neutron fields, reaction rates, nuclide inventories, radioactivity, dose rates, decay heat, …?

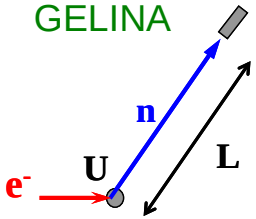
What is the penalty for inaccuracy?
- Safety margins for power distribution, reactivity coefficients, burnup/time to refuel, enrichment, shielding, spent fuel storage, …
- We miss processes with low probability

Nuclear Data facilities at JRC-IRMM

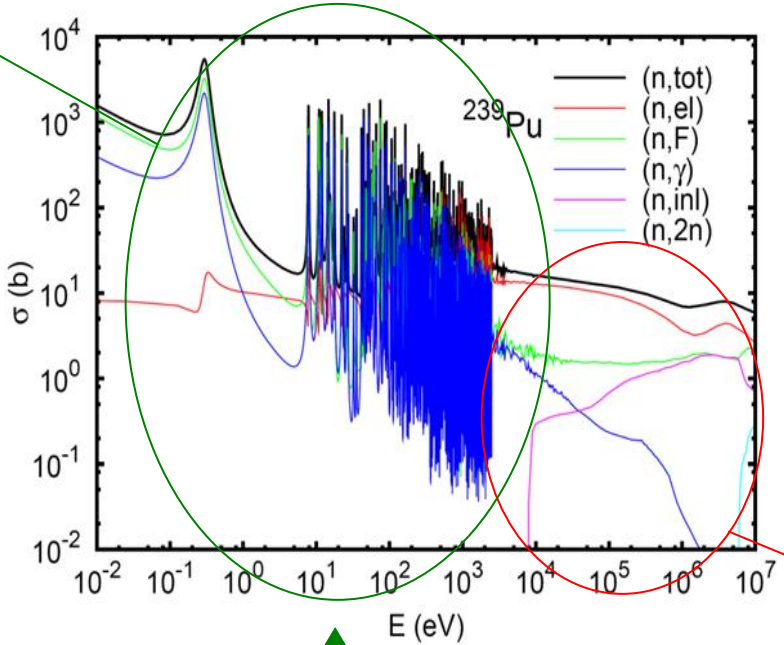
European Commission

Time-of-flight measurements

GELINA



$$E = \frac{1}{2}mv^2 \propto \left(\frac{L}{T}\right)^2$$



energy resolution

Van de Graaff / MONNET

Mono-energetic neutron beams

n

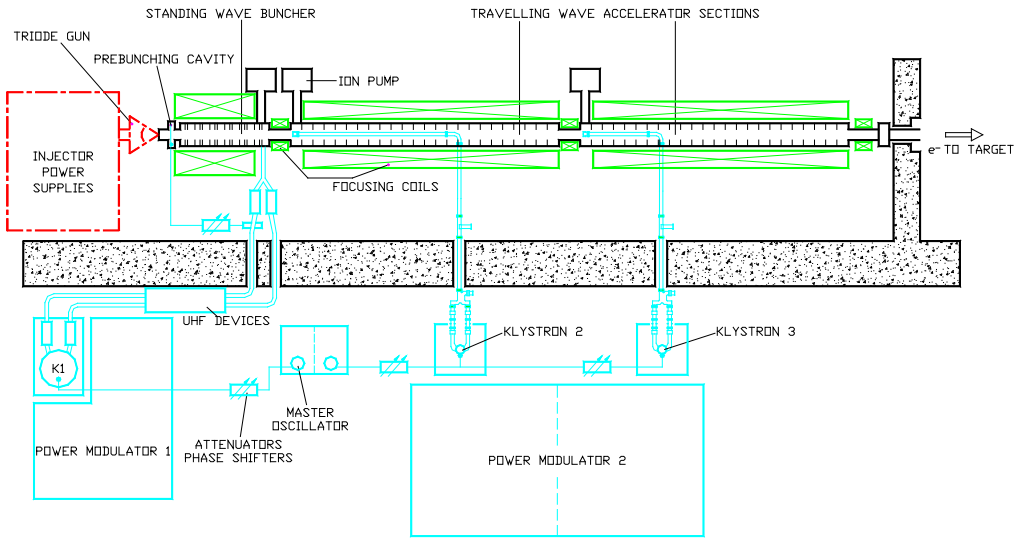
Ti/T

d

α


Van de Graaff mono-energetic neutron source
GELINA neutron time-of-flight facility

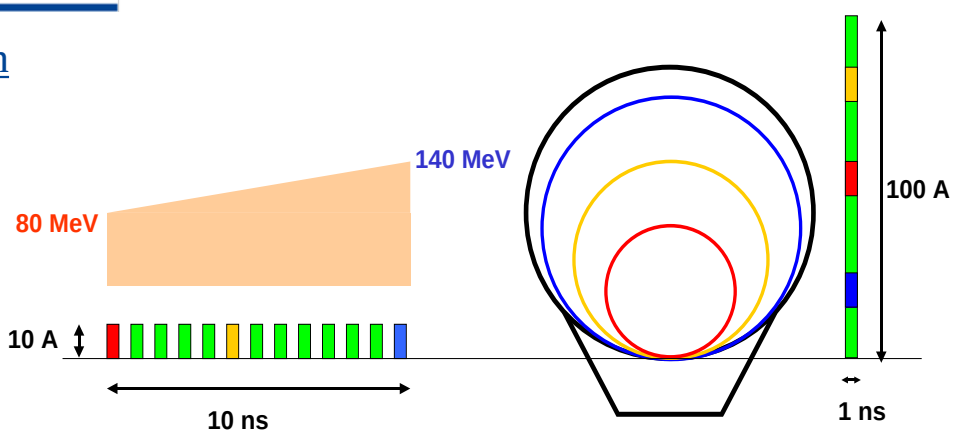
GELINA

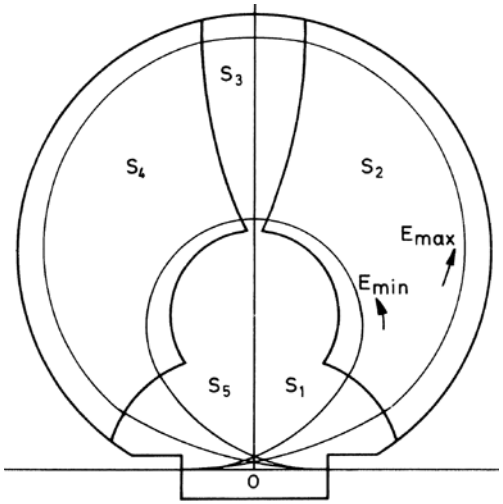

STANDING WAVE BUNCHER
TRAVELLING WAVE ACCELERATOR SECTIONS
TRIODE GUN
PREBUNCHING CAVITY
ION PUMP
INJECTOR POWER SUPPLIES
e⁻ TO TARGET
FOCUSING COILS
UHF DEVICES
KLYSTRON 2
KLYSTRON 3
K1
MASTER OSCILLATOR
ATTENUATORS PHASE SHIFTERS
POWER MODULATOR 1
POWER MODULATOR 2

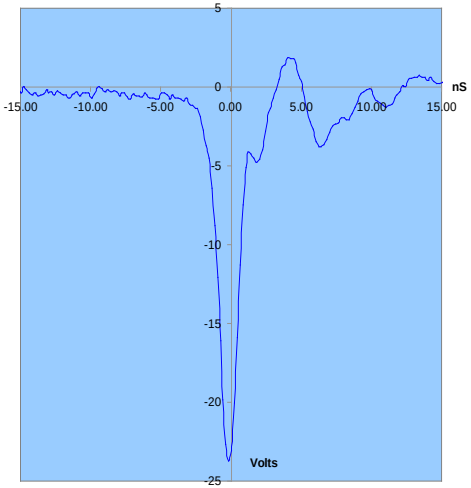
European Commission

measurements with very high energy resolution
using the neutron **time-of-flight** technique

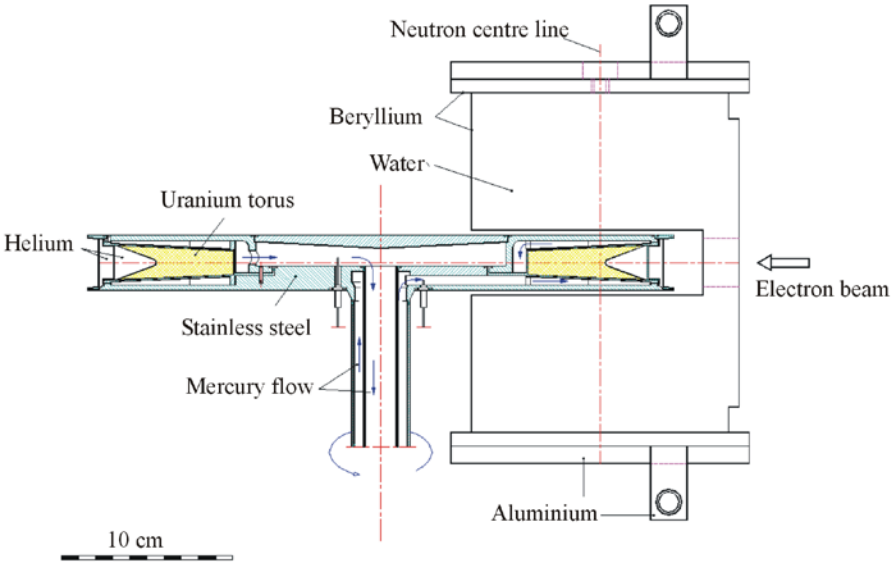
$$\frac{\Delta E_n}{E_n} = \frac{2}{L}\sqrt{(\Delta L)^2 + 1.9E_n(\Delta t)^2}$$

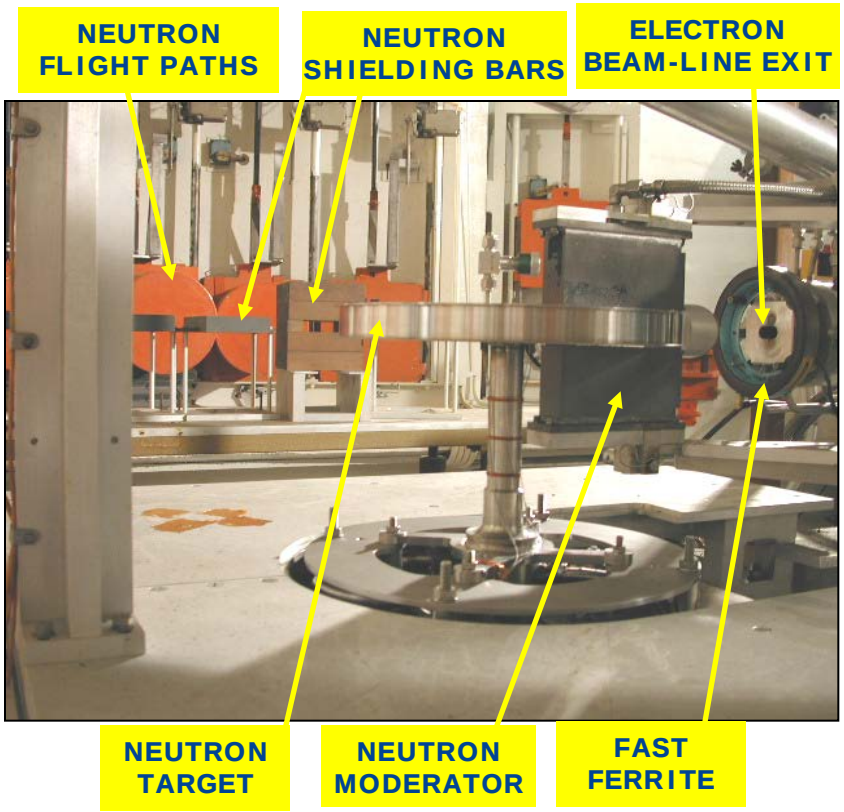


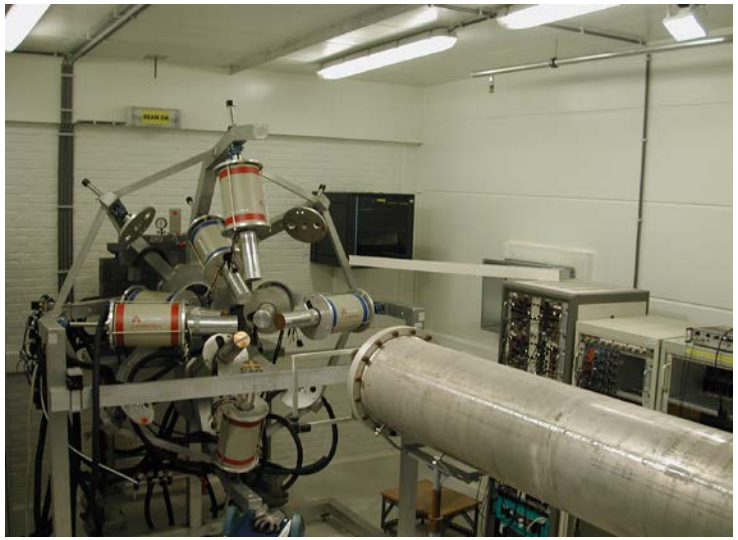




GELINA


Neutron centre line
Beryllium
Water
Uranium torus
Helium
Electron beam
Stainless steel
Mercury flow
Aluminium
10 cm


NEUTRON FLIGHT PATHS
NEUTRON SHIELDING BARS
ELECTRON BEAM-LINE EXIT
NEUTRON TARGET
NEUTRON MODERATOR
FAST FERRITE

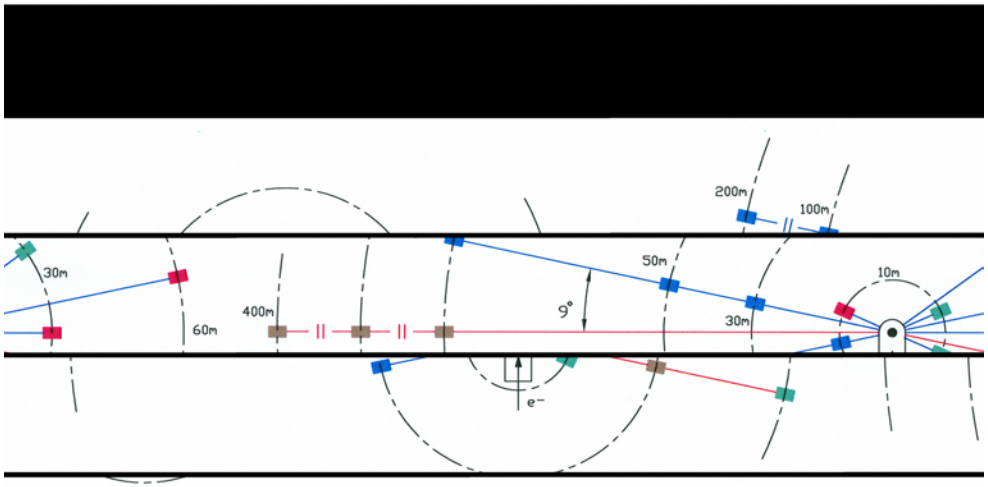


Multi-user facility

10 flight paths with measurement stations at L ~ 10 m - 400 m

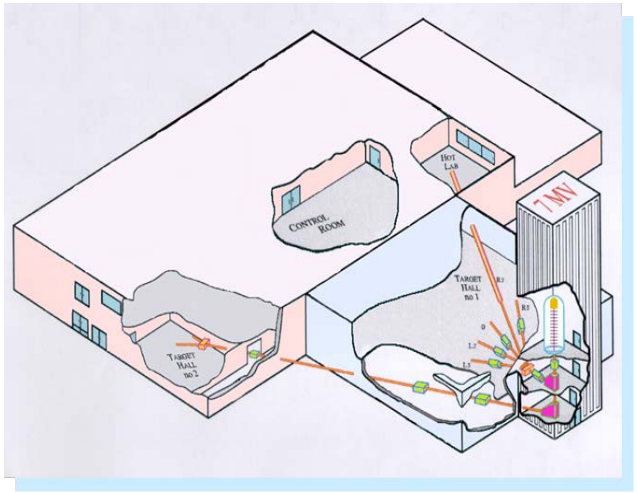
Special equipment to perform:

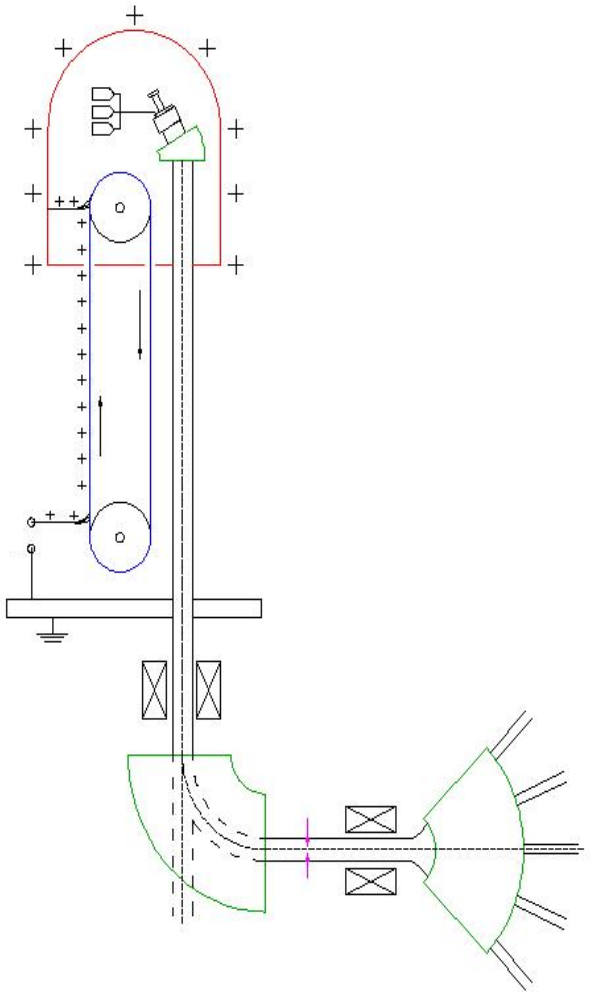
- Total cross section measurements
- Partial cross section measurements
  capture, (in)elastic scattering, fission…



European Commission

7 MV Van de Graaff





Van de Graaff facility

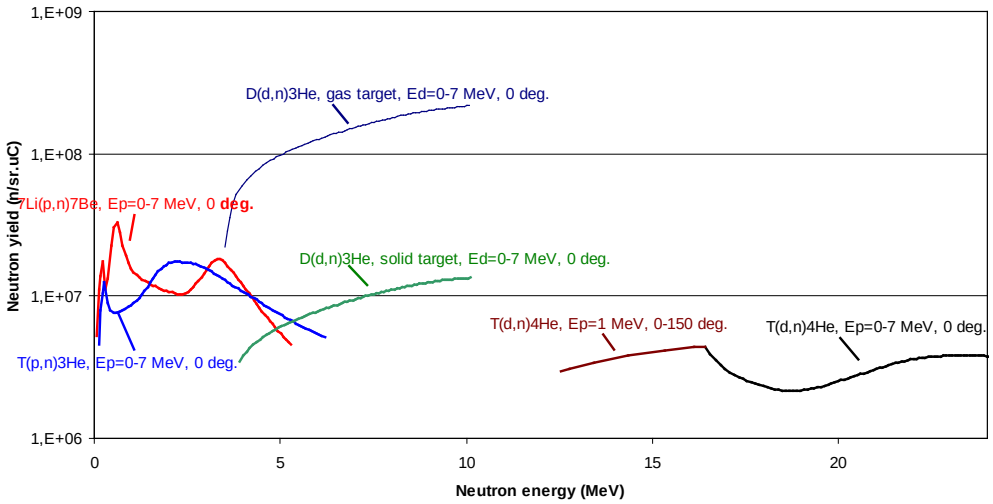
VdG: 7 MV protons, deuterons, α

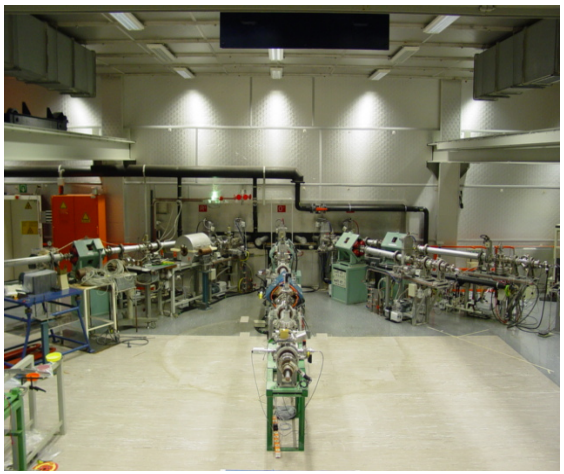
$^{7}Li(p,n)^{7}Be$ E_n: 0 - 5.3 MeV

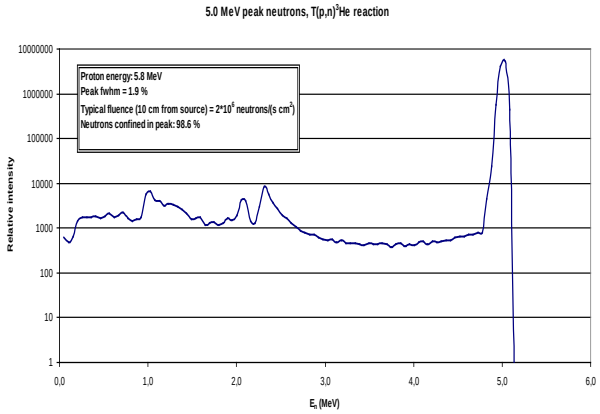
$T(p,n)^{3}He$ E_n: 0 - 6.2 MeV

$D(d,n)^{3}He$ E_n: 1.8 - 10.1 MeV

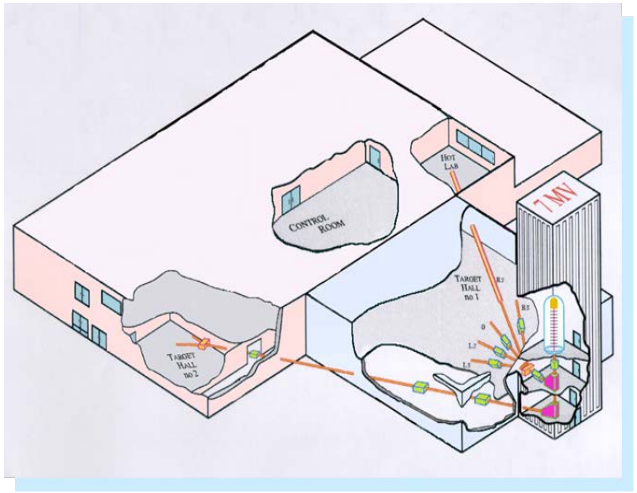
$T(d,n)^{4}He$ E_n: 12.1 - 24.1 MeV







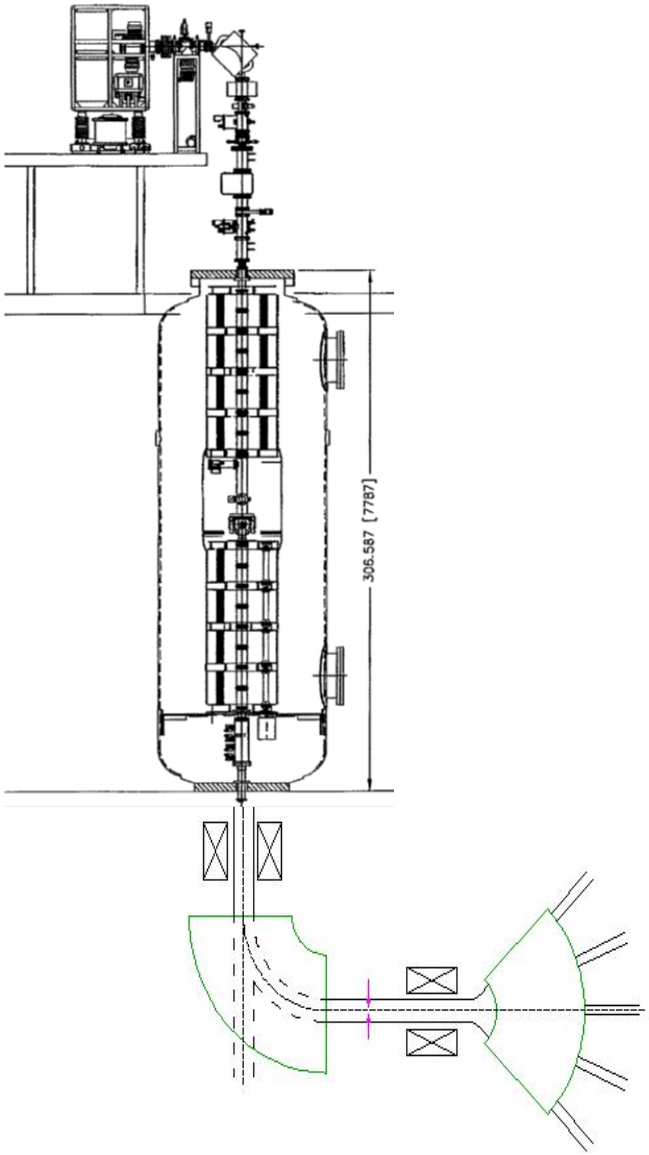
MONNET



7 MV Van de Graaff

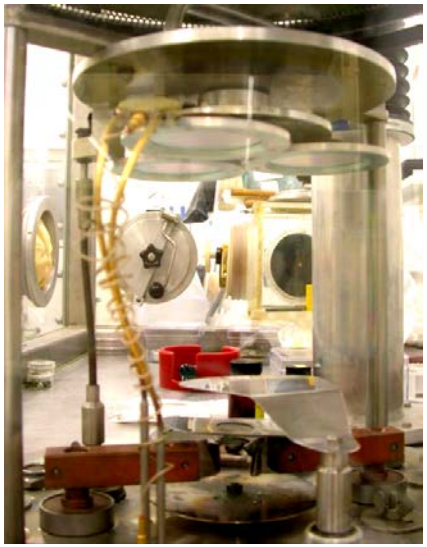
4 MV Tandem

MONNET



Nuclear sample preparation

Production and characterisation of actinide and stable targets for MS laboratories



highly enriched ^{235}U and ^{233}U ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{nat}U, ^{depl}U,
^{238}Pu, ^{239}Pu, ^{240}Pu,^{242}Pu, ^{237}Np, ^{241}Am, ^{243}Am

Thin polyimide foils for fission fragment spectroscopy

Open Access to JRC nuclear facilities

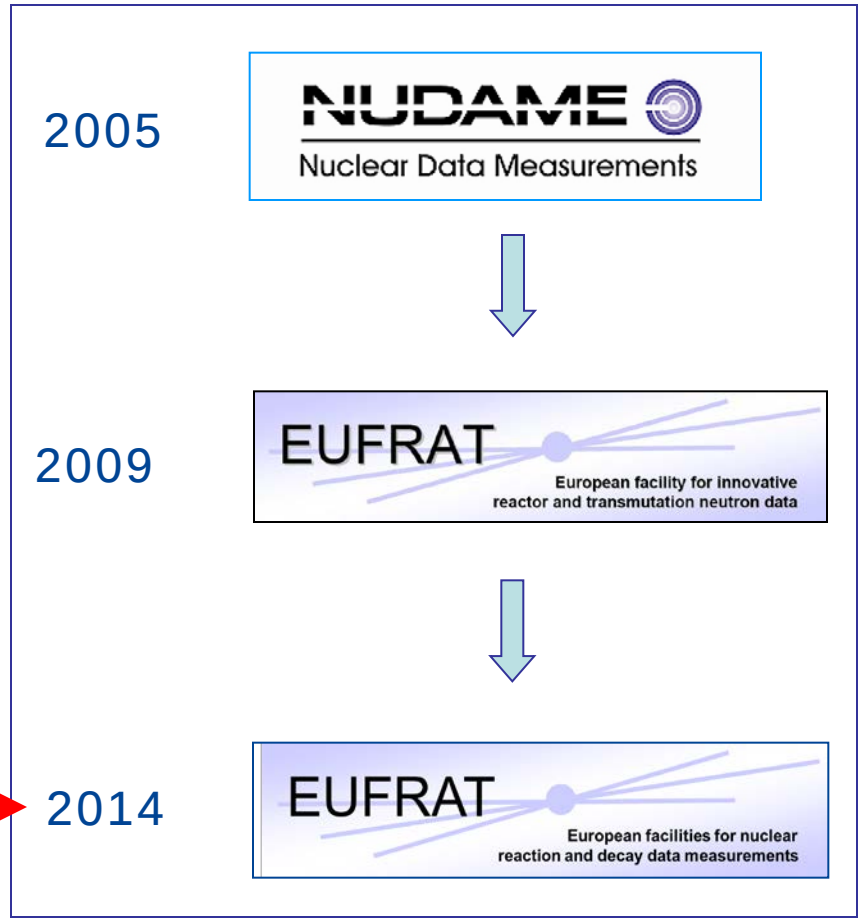
SRIA of SNE-TP (2013):
*'The existing European initiatives for facilitating **transnational access to facilities** for the purpose of education and training should be optimised and coordinated in view of building a European platform for E&T-related facilities.'*

OPEN ACCESS

→ **quality-based access (cfr. ESFRI charter)**

- **scientific excellence**.
- **across disciplinary boundaries**.
- **public procedures.**
- **evaluation through peer review**.

Institutional JRC budget
→ Sustainable access scheme



Open Access to JRC User facilities

European Facilities for Nuclear Reaction and Decay Data Measurements

External users

EUFRAT

European facilities for nuclear reaction and decay data measurements

PAC





https://ec.europa.eu/jrc/eufrat

EUFRAT

Collaborative experiments

Financial support is possible within boundaries defined by PAC

- visiting groups have valuable expertise for SN3S unit
- experiments closely related with on-going JRC-IRMM nuclear projects
- results must have a clear added value for the on-going Euratom Work Programme

Associated experiments

No financial user support

- other experiments in related domains
- clear scientific value
- proven need for the use of one of the JRC-IRMM facilities

Measurement time

Best possible measurement conditions

Scientific and technical support

Administrative and logistic support

Training (if necessary)

After 2 EUFRAT calls (2014)
24 approved experiments

Research groups from **MS**
CEA, CNRS, HZDR, CERN, INFN, NIPNE, ENEA, Universities Cracovia, Uppsala, Tartu

+ 3rd countries
JAEA, ORNL, Kiev

Access to Nuclear Data Facilities in Europe

JRC | **Consortia of ND facilities**

2005

NUDAME
Nuclear Data Measurements

9 partners

2009

EUFRAT
European facility for innovative reactor and transmutation neutron data

ERINDA
European Research Infrastructures for Nuclear Data Applications

13 partners

2014

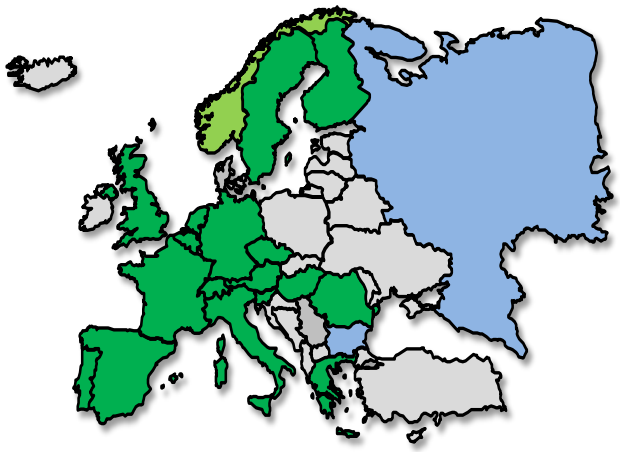
EUFRAT
European facilities for nuclear reaction and decay data measurements

CHANDA
SOLVING CHALLENGES IN NUCLEAR DATA FOR THE SAFETY OF EUROPEAN NUCLEAR FACILITIES
SEVENTH FRAMEWORK PROGRAMME

35 partners

CHANDA

Challenges in nuclear data for the safety of European nuclear facilities



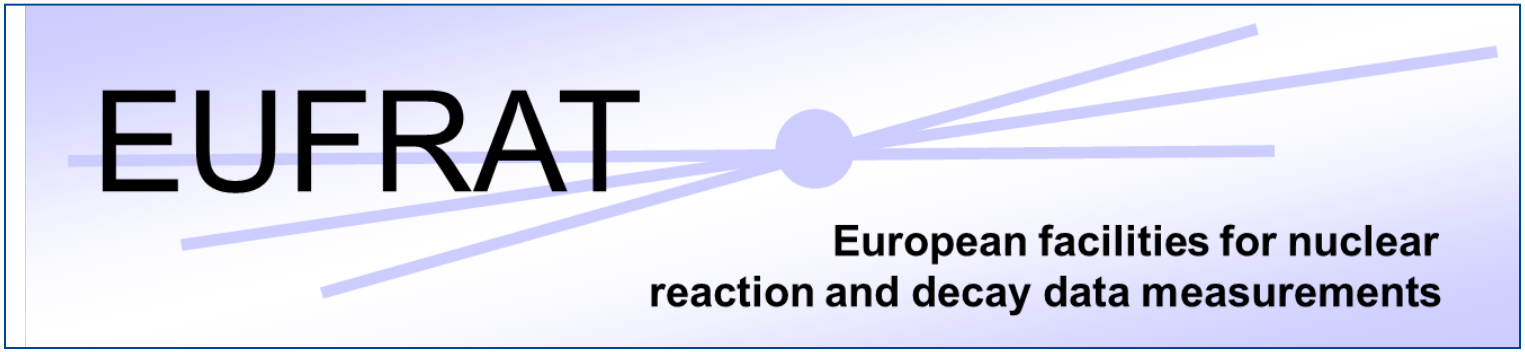
CHANDA: 35 participants (18 countries)

2013-2017

35 partners
CIEMAT, ANSALDO, CCFE, CEA, CERN, CNRS, CSIC, ENEA, GANIL, GSI, HZDR, IFIN-HH, INFN, IST-ID, JRC, JSI, JYU, KFKI, NNL, NPI, NPL, NRG, NTUA, PSI, PTB, SCK, TUW, UB, UFrank, UMainz, UMan, UPC, UPM, USC, UU, UOslo

Infrastructure coordination & development

New neutron beams, new experimental equipment, new evaluation methods, Myrrha safety case, access to validation experiments, transnational access, target preparation



A few examples of recent EUFRAT experiments

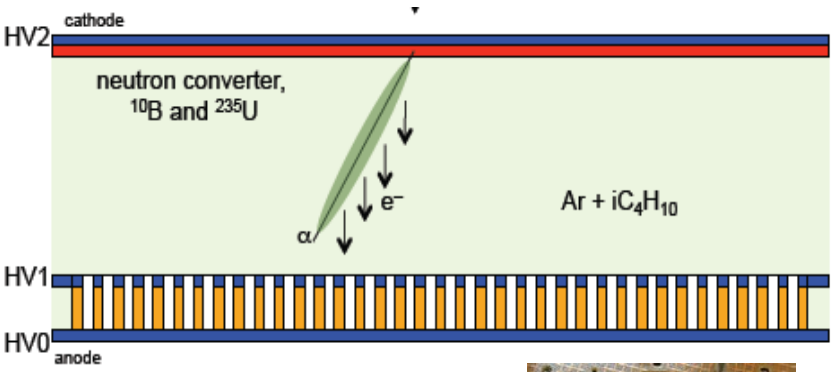
Test of XY-MGAS detector for n_TOF

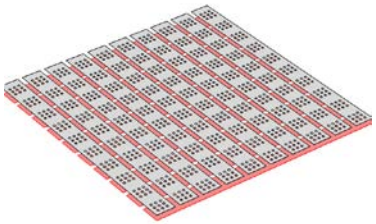
European Commission

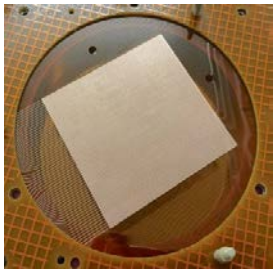
Berthoumieux et al., CEA Saclay

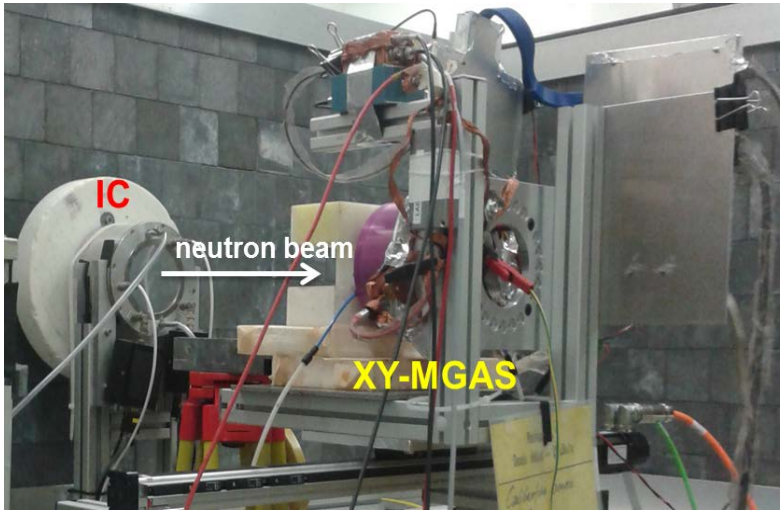
- Newly developed n_TOF MicroMegas neutron monitor
  - segmented mesh and anode
  - low mass ➔permanently in beam
  - neutron fluence and beam profile
  - 20µg/cm^2 ^{10}B neutron converter on aluminised mylar backing
  - P10 detector gas

- Test at GELINA FP5/10 m in January 2015
  - Test of detector operation with real neutron beam
  - Test of amplitude signal
  - Preliminary test of position reconstruction









Improved cross sections for criticality safety

European Commission

Guber et al., ORNL

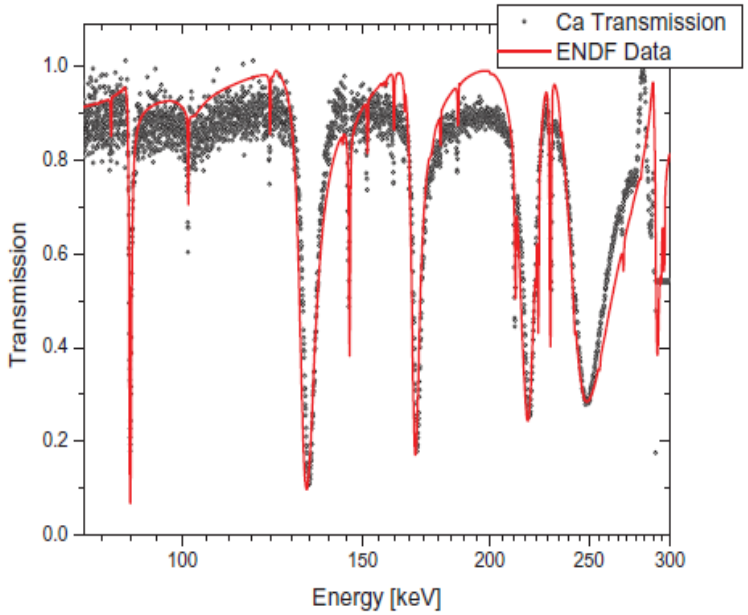
Nuclear data in support of US DOE Nuclear Criticality Safety Program (NCSP)

- Evaluated data underperform in criticality calculations
- Missing covariance data

- Calcium
  - Structural material and nuclear waste storage (concrete)
- Cerium
  - Used in chemical process streams as catalyst + high yield fission product
- Vanadium
  - Key structural element

Neutron cross section measurements

- Capture (GELINA FP14/60m)
- Transmission (GELINA FP4/50m)



Inelastic neutron scattering cross-section measurements on actinides - GRAPHEME

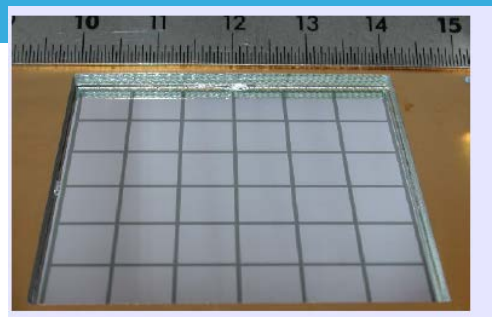
$^{238,235,233}U$, ^{232}Th, ^{nat}W, ^{nat}Zr

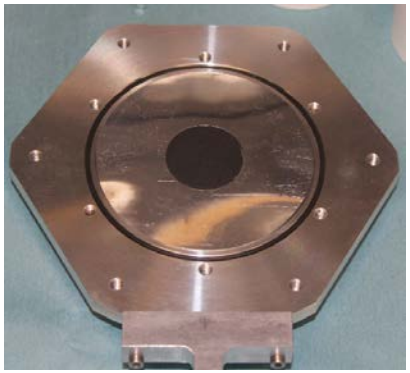
European Commission

Dessagne et al., CNRS/IPHC Strasbourg

Target 8.3 g, 3 GBq, 30mmØ x 0.64 mm
IRMM Target preparation lab (metal disk).

$^{233}U(n,n'g)$



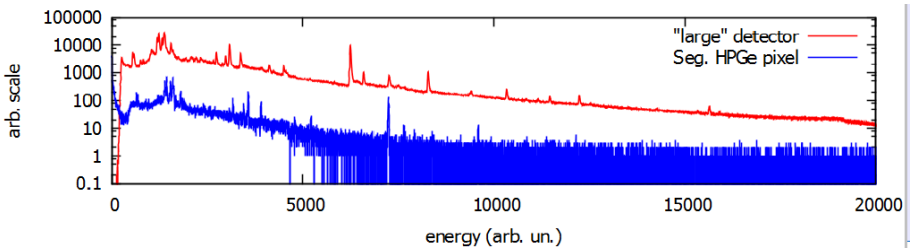


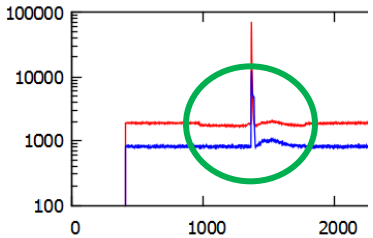
GRAPhEME upgrade: Segmented HPGe in 36 Pixels

- Ge crystal 54 by 54 mm, 20 mm thick
- 6x6 pixels (6.66 by 6.66 mm)
- Extensive tests and simulations for precise characterization

36 fold segmented planar germanium detector
Cope with high count rate from radioactivity

→ Increased *granularity* to reduce sensitivity to radioactivity and γ flash





Clearly reduced dead time for single pixels.

One digitizer channel per pixel.

Inelastic neutron scattering cross-section measurements on actinides - GAINS

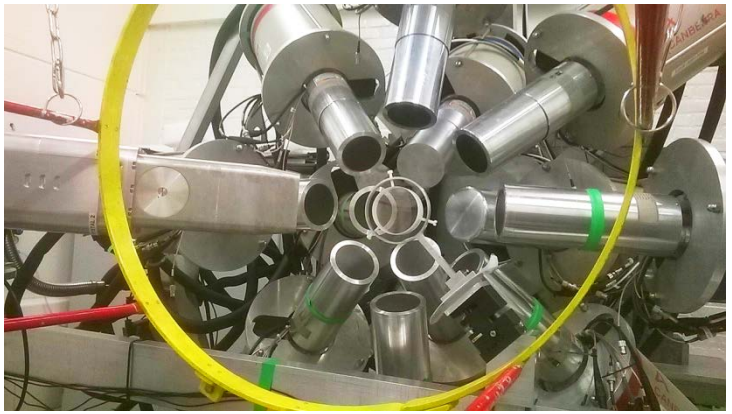
European Commission

^{16}O ^{48}Ti

Negret et al., NIPNE, Bucharest

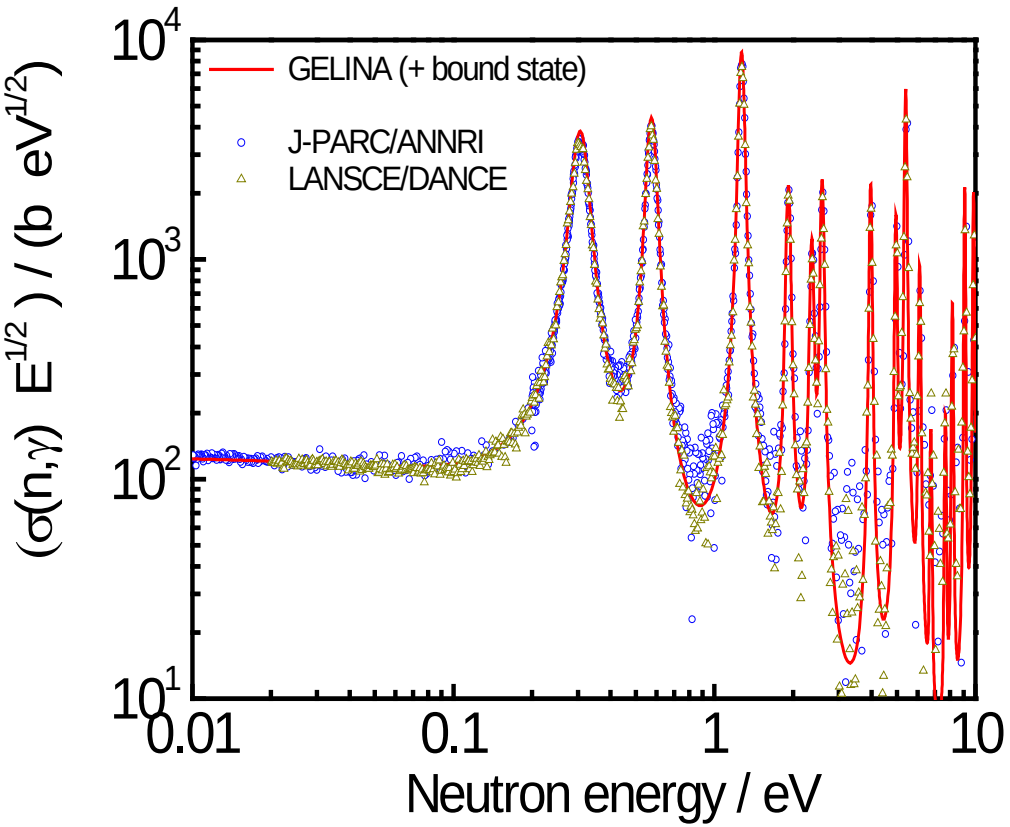
GAINS: Germanium Array for Inelastic Neutron Scattering

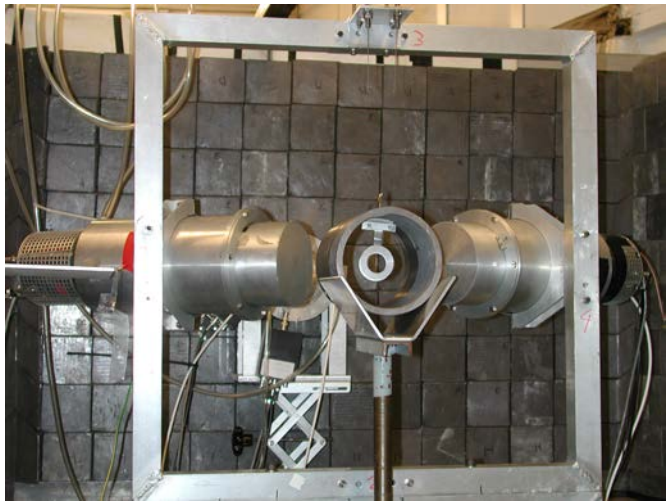
12 HPGe 80 mm ø x 80 mm L
1 keV resolution at 1 MeV (neutrons)



European Commission

Schillebeeckx et al.





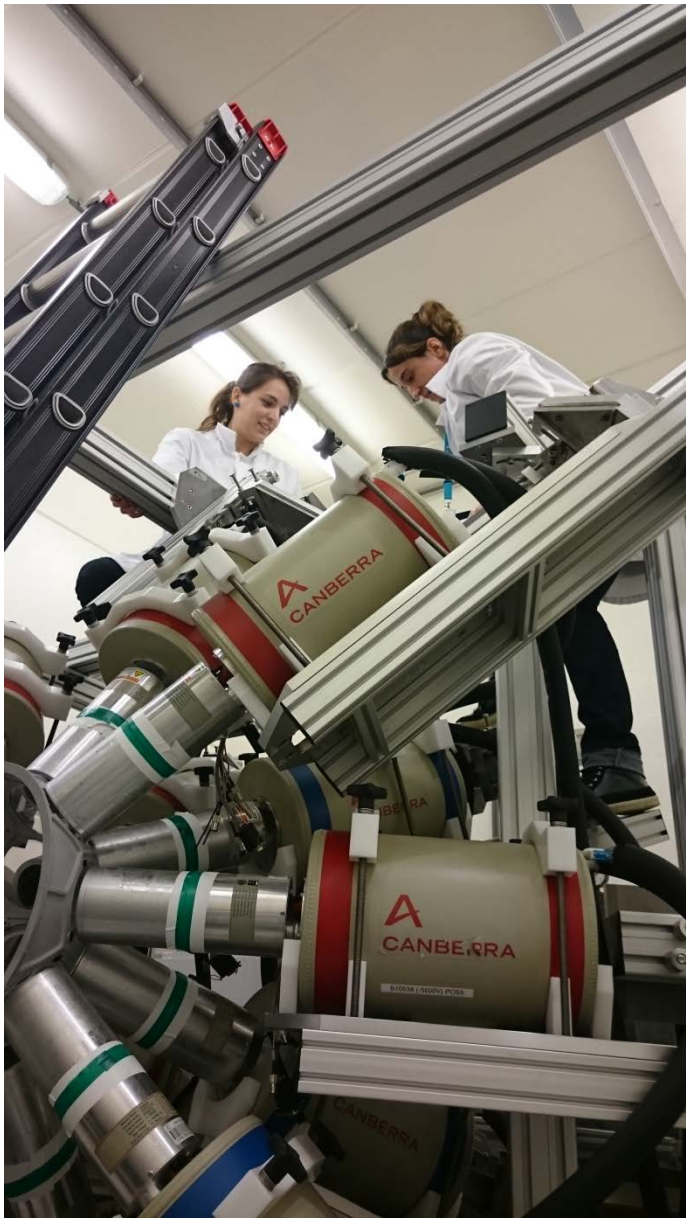
J-PARC/ANNRI
LANSCE/DANCE

normalized to
$\sigma(n_{th},\gamma)$ = 749 b

Other experiments

- **γγ-coincidence measurements**
  (branching ratios, missing levels)
- **Prompt Neutron multiplicities**
  Detection of neutrons amongst large γ-background
- **Fission cross section measurements**
  Thin targets ^{235,238}U, ^{237}Np, ^{242}Pu
- **Detector and dosimeter characterisation**
  Detector response in known neutron fields

...



Conclusions

- JRC is successfully running since a decade open-access programmes in the nuclear data domain.

- Offer unique research and training opportunities complementing those existing in the MS.

- A large proportion were (1) first-time users and (2) PhD students and Postdocs.

- Many new and long-term collaborations evolved.

- Close interaction with all major consortia pooling European research efforts

- In 2014, JRC open-access projects became direct actions, creating a sustainable framework for access to JRC facilities.

https://ec.europa.eu/jrc/eufrat