EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

Joint Research Centre

High Resolution Neutron Cross Section Measurements at GELINA

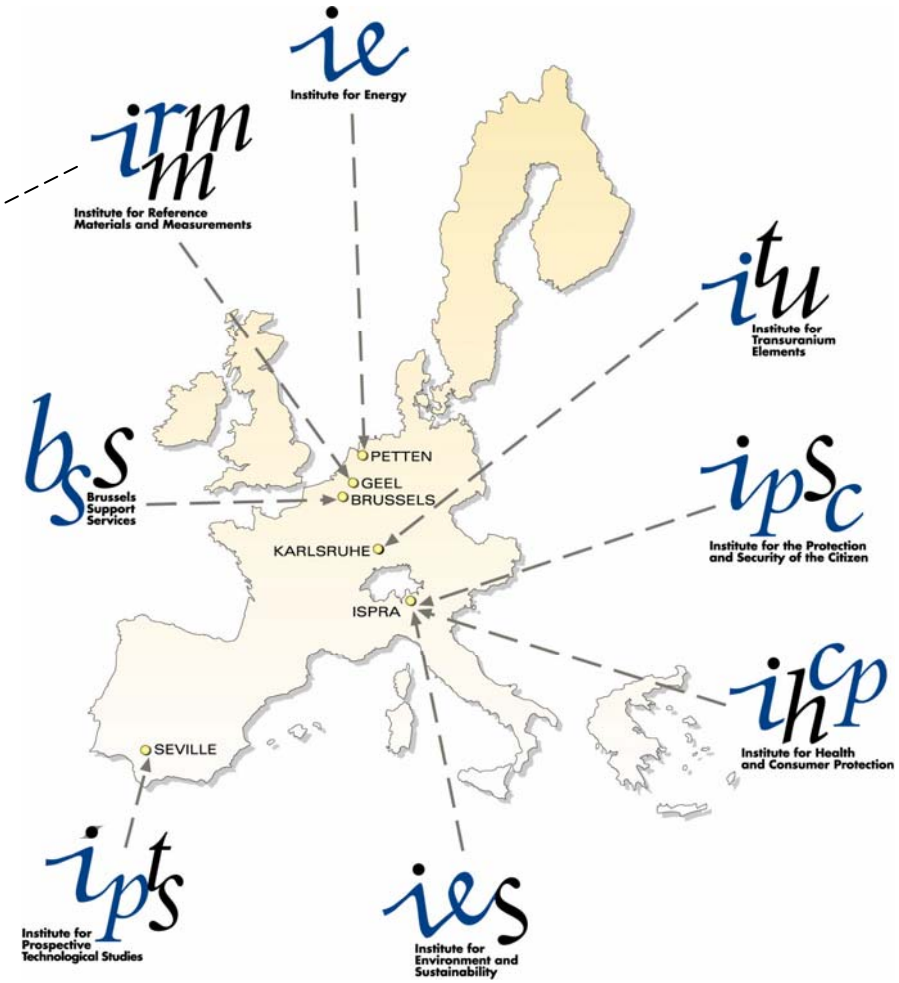
Institute for Reference Materials and Measurements (IRMM)
Geel, Belgium

http://www.irmm.jrc.be
http://www.jrc.cec.eu.int

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

EC - JRC - IRMM

Institute for Reference Materials and Measurements



EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

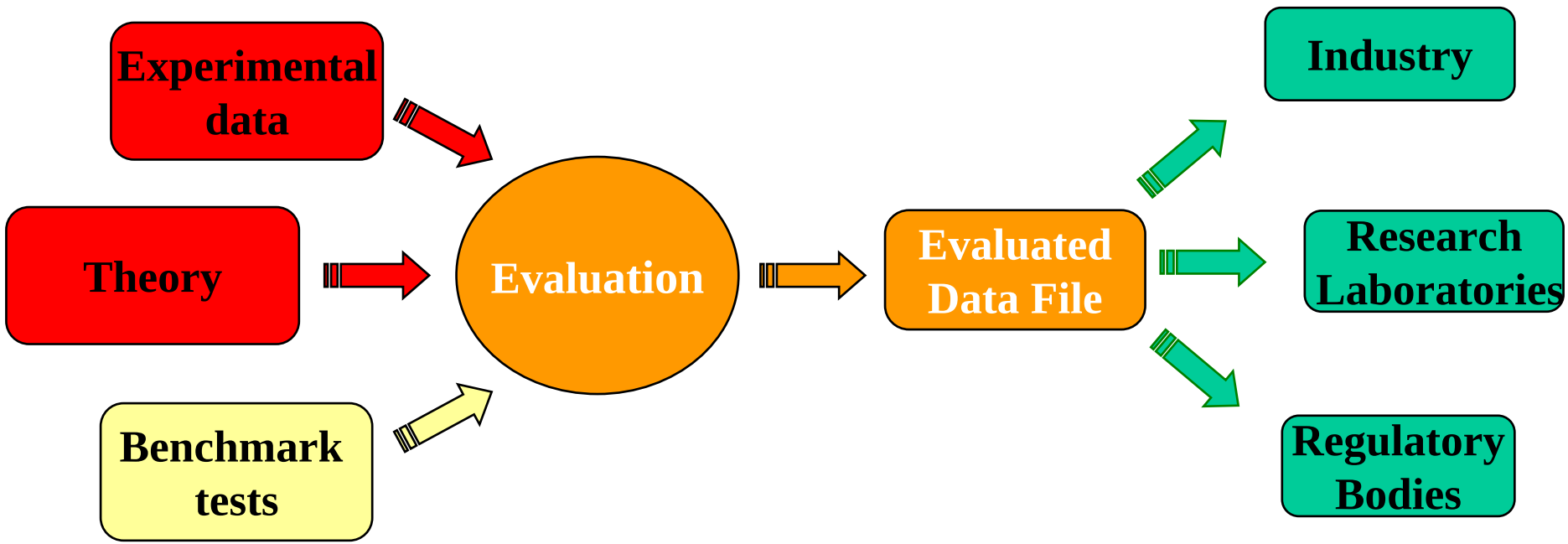
Institute for Reference Materials and Measurements (IRMM)

- **Multi-disciplinary research institute**
- **Structured around five research units**
  - Reference Materials (RM)
  - Isotope Measurements (IM)
  - Food Safety and Quality (FSQ)
  - Scientific Quality and Strategy (SQS)
  - **Neutron Physics (NP)**

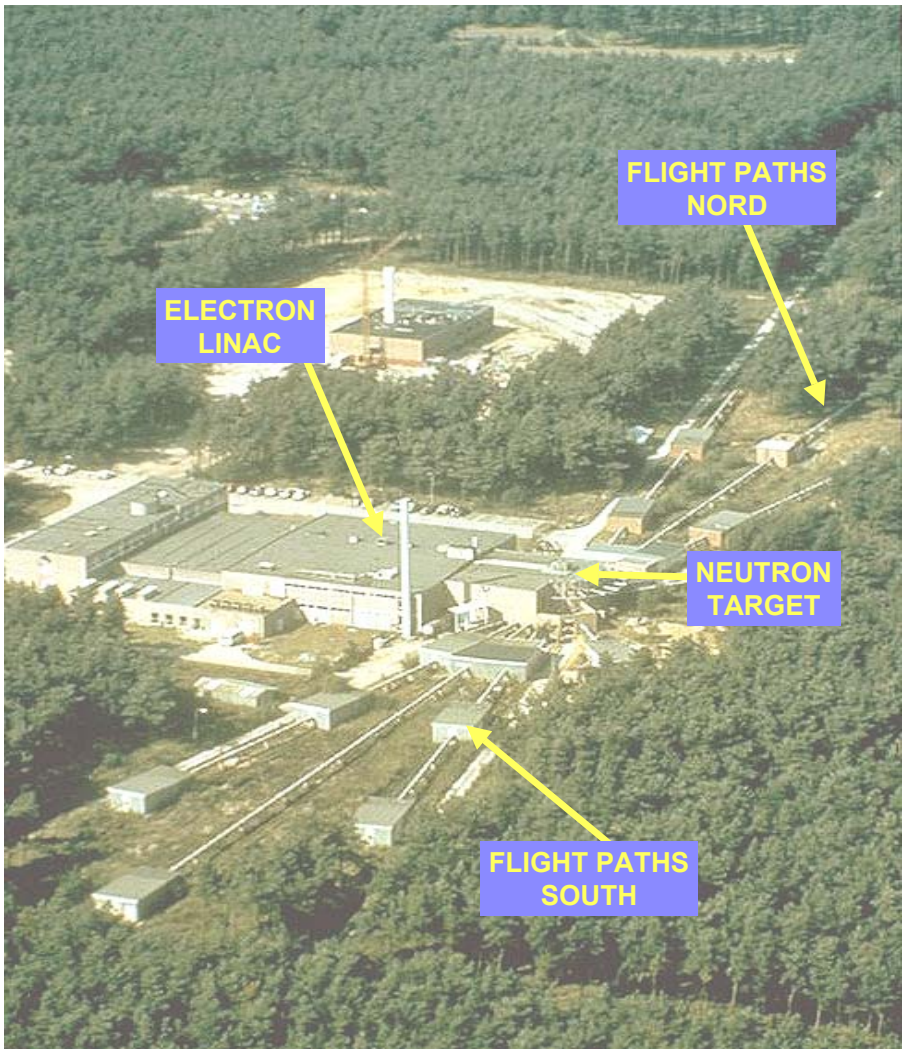
The Mission of the Neutron Physics Unit

Provide European safety authorities and industry with neutron reaction data for:

- **The *safety* assessment of nuclear installations and the nuclear fuel cycle**
- **The *feasibility* study and *development* of waste transmutation facilities and innovative reactor systems**



GELINA



- **Pulsed white neutron source**

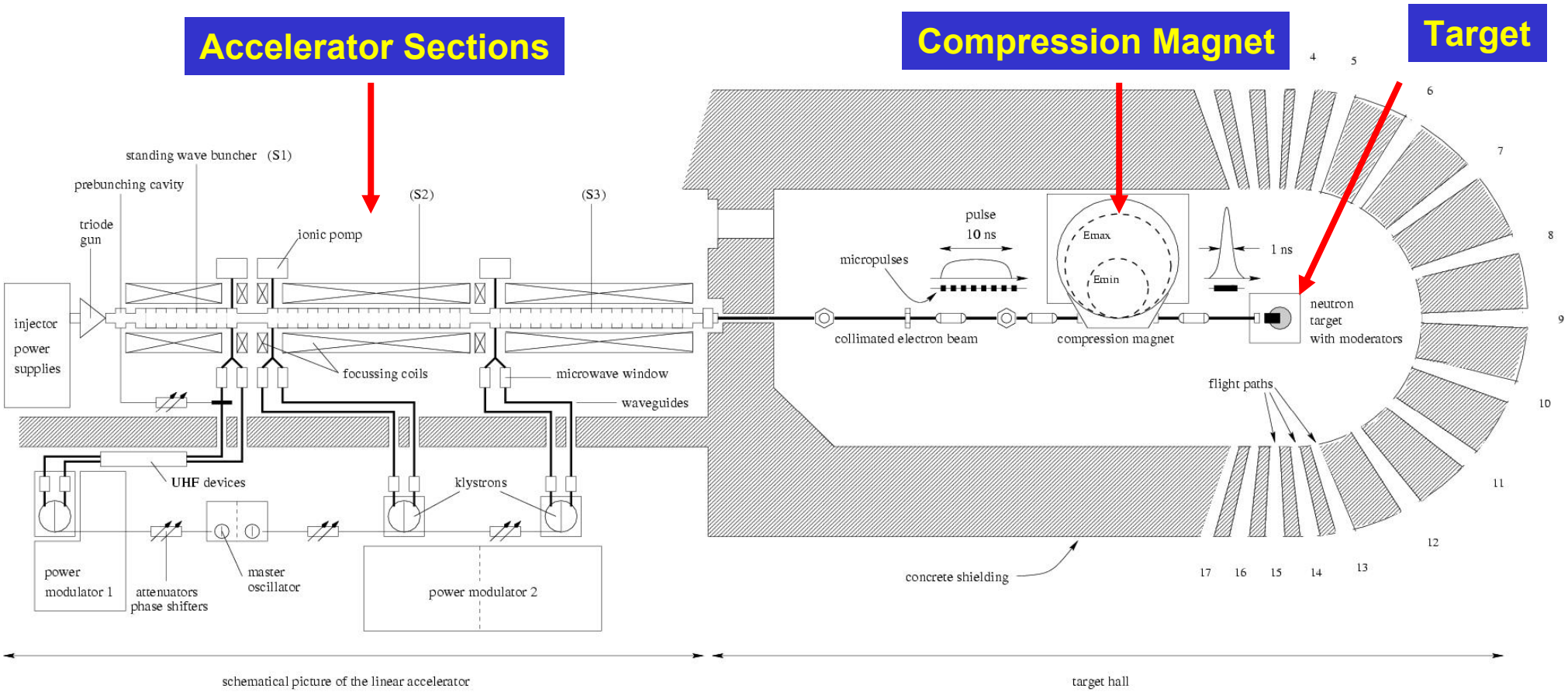
  (1 meV < E_n < 20 MeV)

- **Neutron energy by Time-Of-Flight (TOF)**

$$E_n = \frac{1}{2} m_n v_n^2 = \frac{1}{2} m_n \left(\frac{L}{t} \right)^2$$

- **Multi-user facility**
- **12 Flight Paths with varying L (8 - 400 m)**
- **The measurement stations have special equipment to perform:**
  - **Total cross section measurements**
  - **Partial cross section measurements**

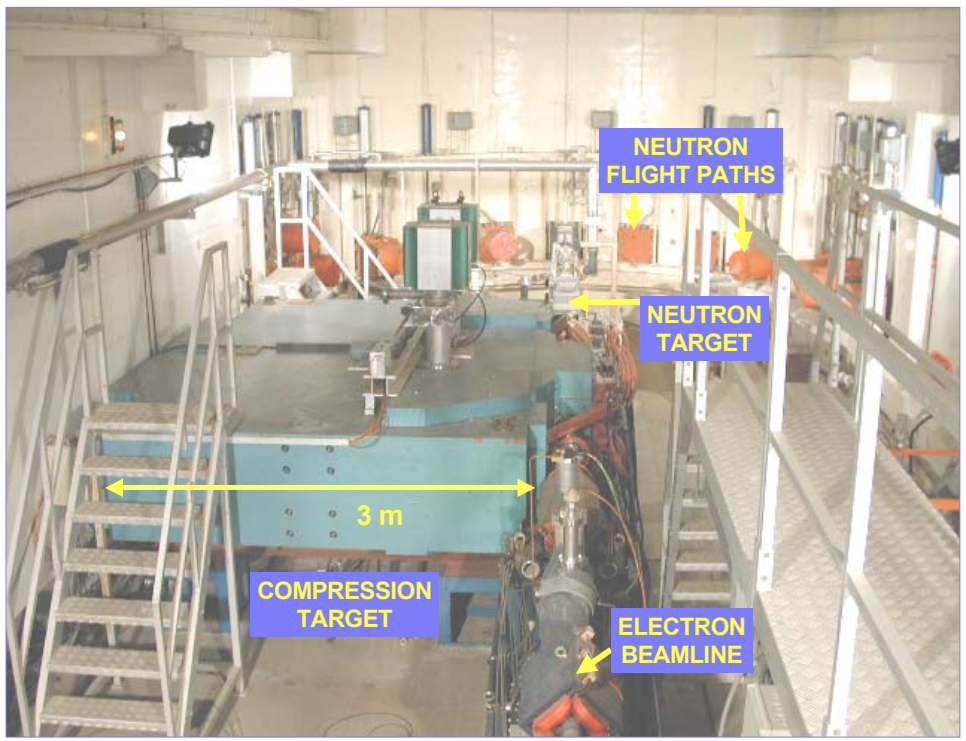
GELINA

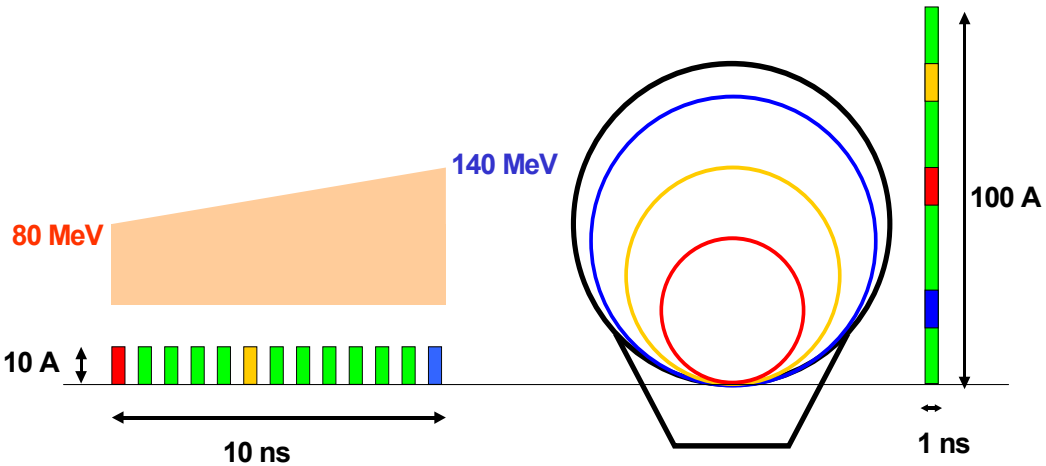


Normal Operation Parameters

Average Current	: 75 μA	Frequency	: 800 Hz
Average Electron Energy	: 100 MeV	Pulse Width	: 1 ns
Mean Power	: 7.5 kW	Neutron Intensity	: 2.5 x 10^{13} n/s

Compression Magnet





$$B\rho = \frac{p}{q};\ E \cong pc;\ q = e$$

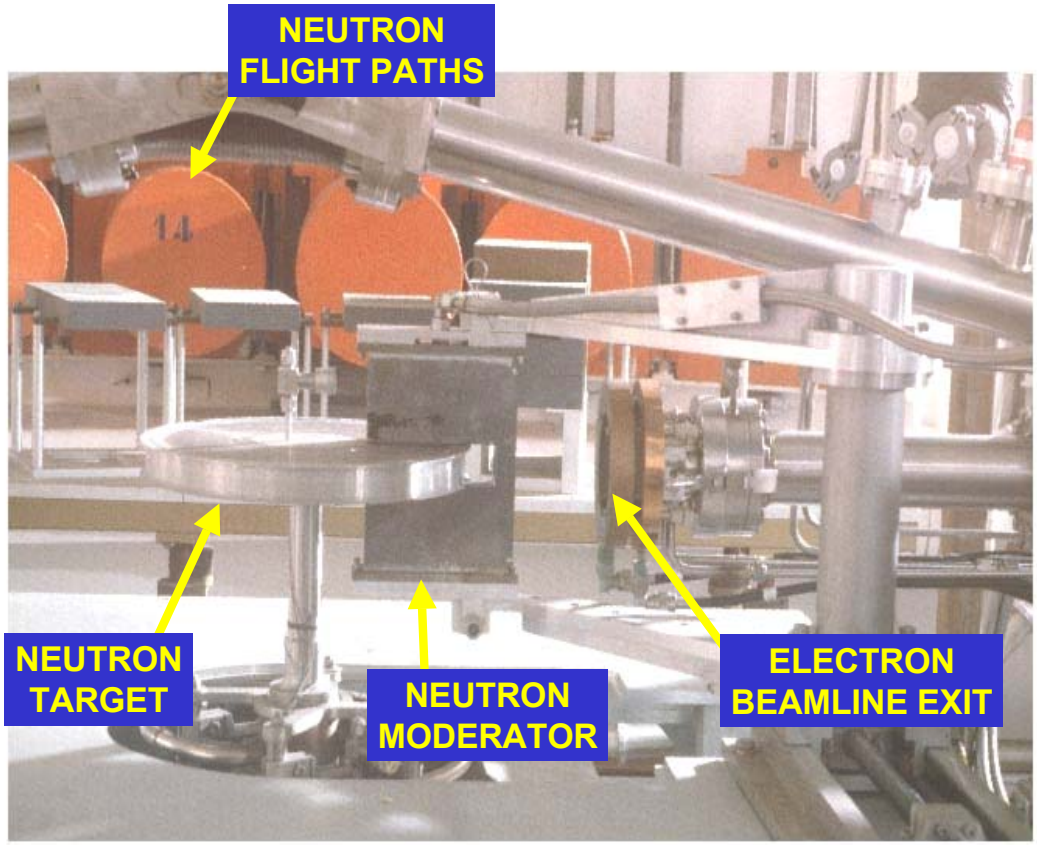
$$\Rightarrow \quad \rho = \frac{1}{B}\frac{E}{qc}$$

$$\Rightarrow \quad B = \frac{2\pi}{qc^2}\frac{\Delta E}{\Delta \tau}$$

ΔE = 60 MeV
$\Delta \tau$ = 10 ns

➔ **compressed pulse length ~ 1 ns**

Neutron Production

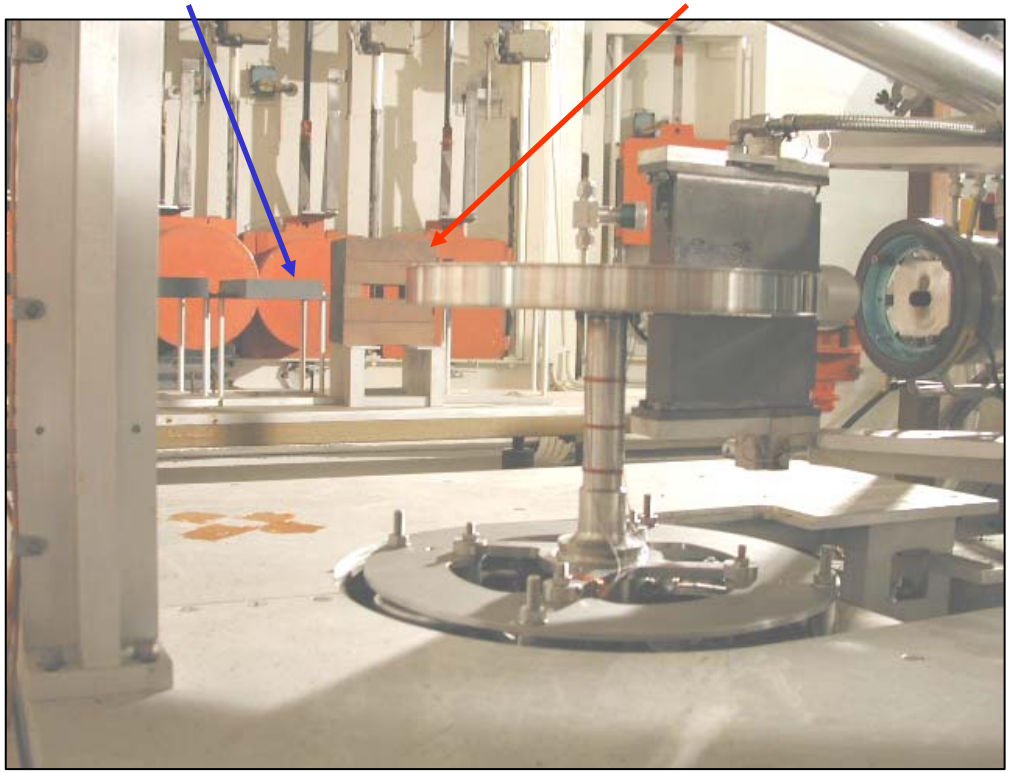


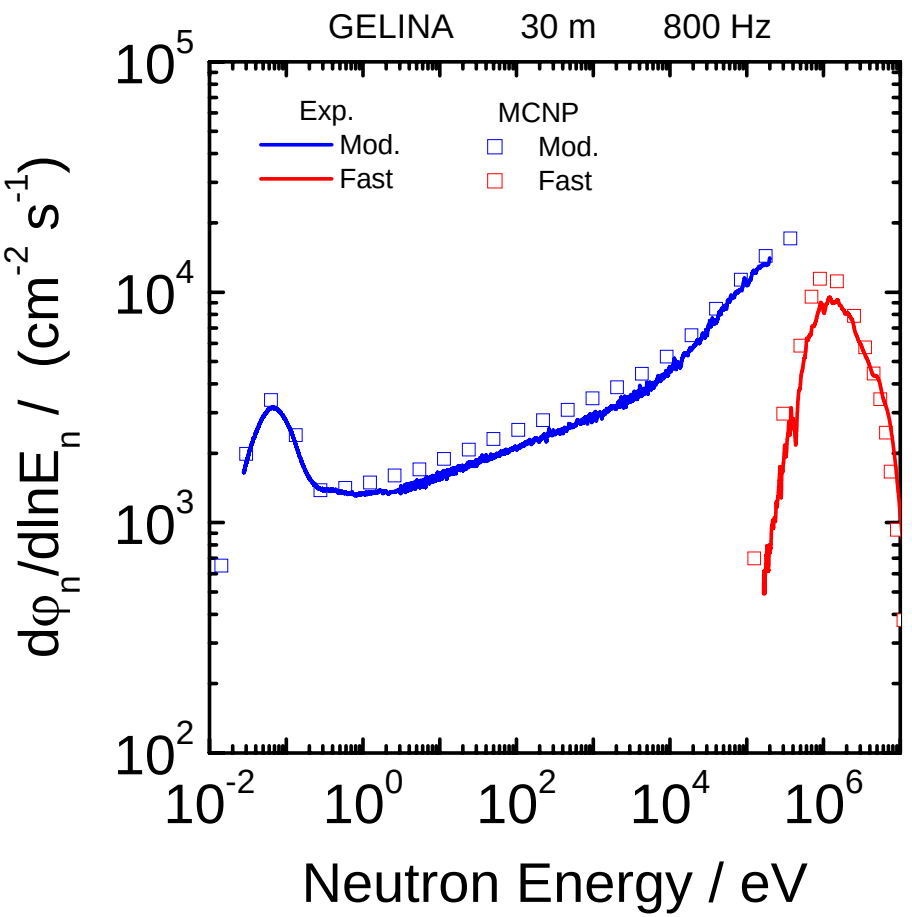
- e^- accelerated to $E_{e^-,max} \approx 140$ MeV
- (e^-, γ) Bremsstrahlung in U-target (rotating & Hg-cooled)
- (γ , n) , (γ , f) in U-target
- Low energy neutrons by water moderator in Be-canning

Neutron Production

SHIELDING MODERATED SPECTRUM

SHIELDING FAST SPECTRUM

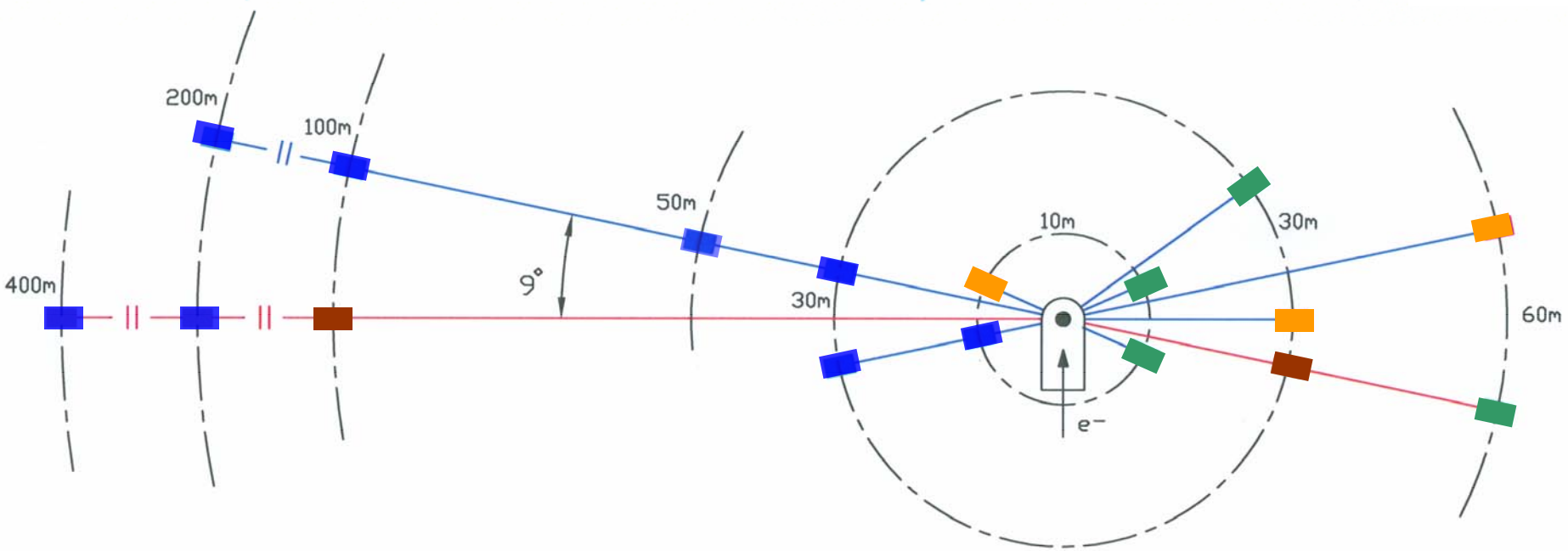




Average Current	**: 75 μA**
Average Electron Energy	**: 100 MeV**
Pulse Width	**: 1ns**
Frequency	**: 40 – 800 Hz**

Measurement stations

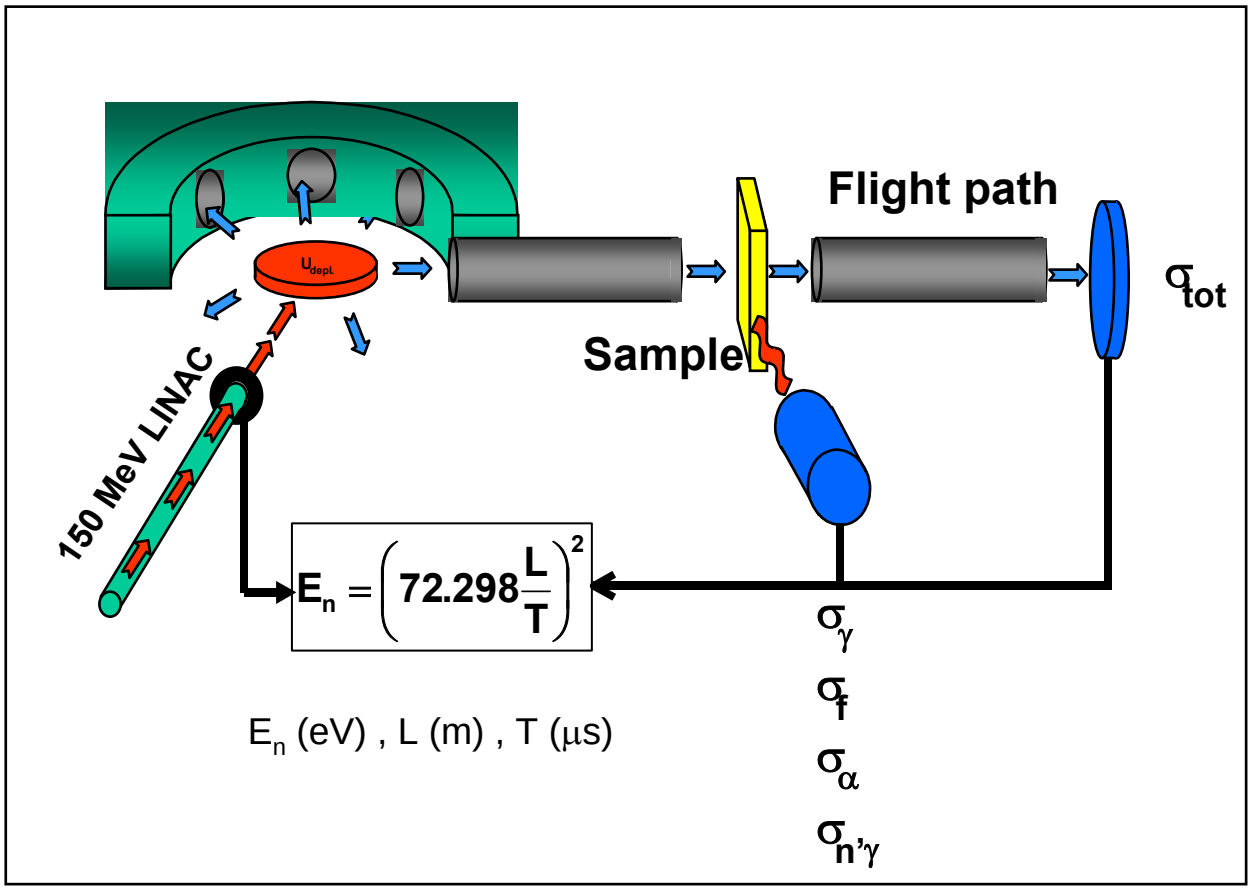
Direct spectrum
Moderated spectrum



(n,γ)	j.nima.2007.03.034
(n,tot)	NP A 773, 173 (2006)
(n,f) and (n,cp)	NSE 156, 211 (2007)
(n,n'γ)	NP A 786, 1 (2007)

- **Ge-detectors (L = 10 m)**
  - Spin and parity PR C 61, 054616 (2000)
  - Partial cross sections & branching ratio
  - Isotope identification
- **C_6D_6 detectors (L = 10, 30 and 60 m)**
  - Parameterisation of $\sigma(n,\gamma)$

TOF-Measurements
Total and Partial Cross-Sections



- **Neutron Flux** $\Rightarrow$ **L** ↘

$$\varphi_n(L) \propto \frac{1}{L^2}$$

- **Resolution** $\Rightarrow$ **L** ↗

$$\frac{\Delta E_n}{E_n} = \frac{1}{L}\sqrt{\frac{E_n \Delta T^2}{\alpha} + \Delta L^2}$$

We need to adapt the flight path length and operation conditions

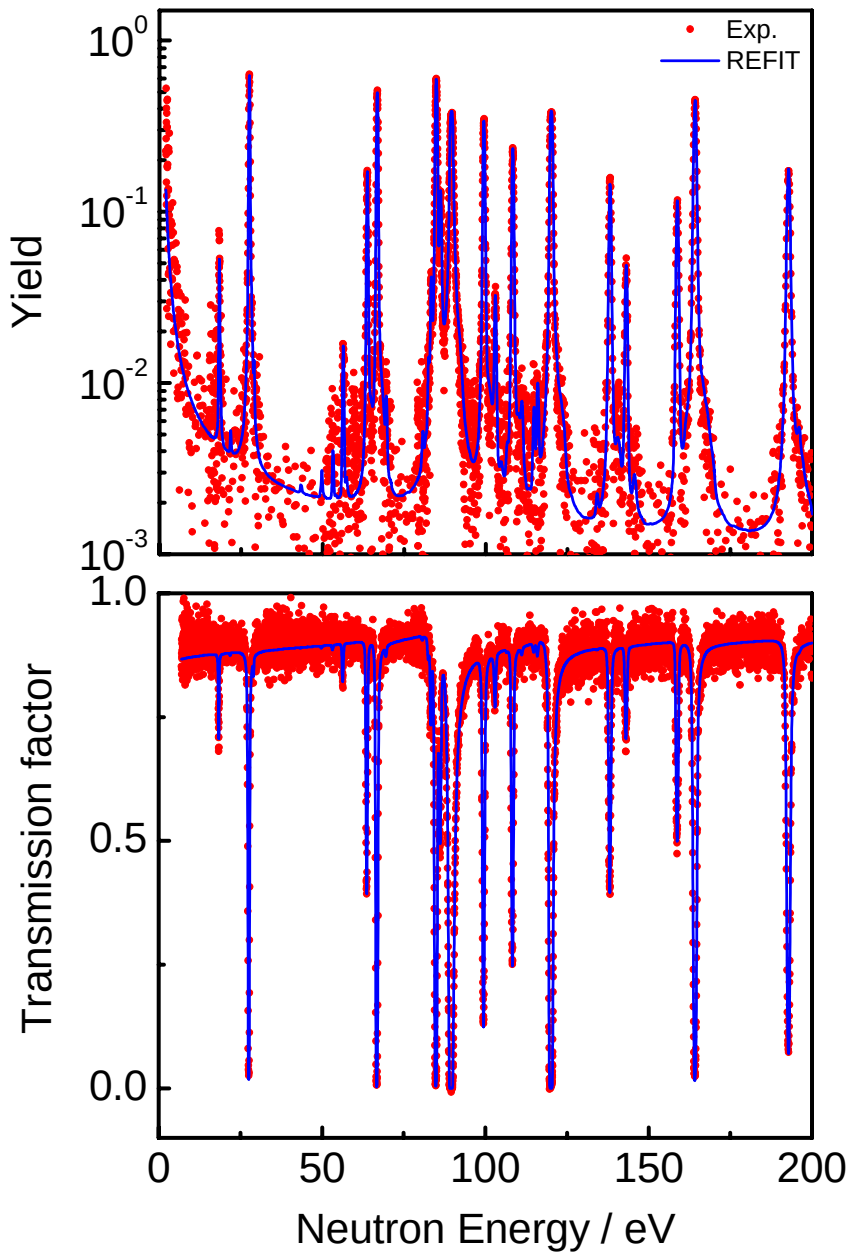
to the required resolution and neutron flux

Contribution to CRP "Reference data for Neutron Activation Analysis"

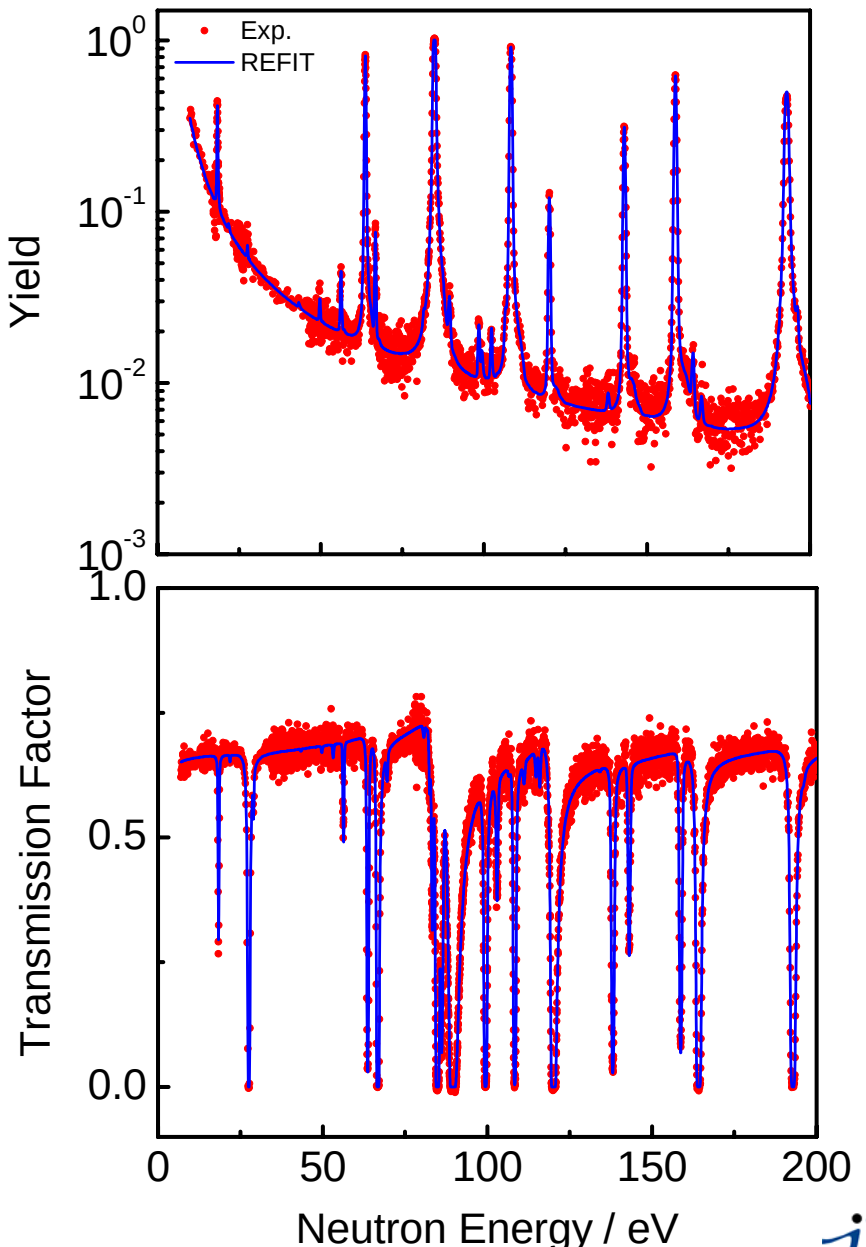
- **New evaluation for ^{nat}Cd** (IAEA, Moxon)
  - total and capture cross section
  - Thermal and RRR
- **New evaluation for ^{197}Au**
  - total and capture cross section
  - Thermal, RRR and URR
- **New evaluation for ^{55}Mn (ORNL)**
  - total and capture cross section
  - RRR and URR
- **Total and capture cross section measurements on W** (INFN Bari)
  - ^{nat}W + enriched isotopes
  - RRR
- **Total and capture cross section measurements on Zr** (INFN Bari)
  - ^{nat}Zr + enriched isotopes
  - RRR

New evaluation for ^{nat}Cd

GELINA : ^{nat}Cd

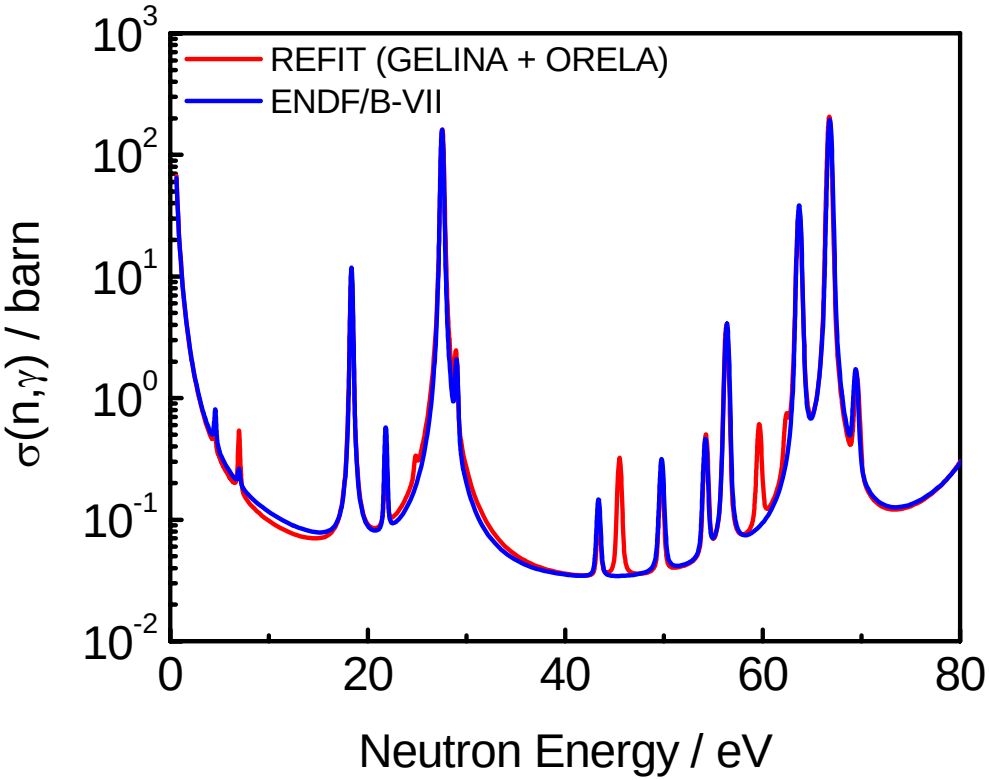


ORELA : ^{113}Cd



New evaluation for ^{nat}Cd

Type	Station		Frequency	Thickness ^{nat}Cd	
	Distance	Angle		atoms/barn	mm
Transmission	*50 m*	*+ 9°*	*50 Hz*	*$1.20\ 10^{-1}$*	*25.00*
	50 m	*+ 9°*	*50 Hz*	*$5.40\ 10^{-4}$*	*0.12*
	50 m	**+ 9°**	**400 Hz**	**$2.34\ 10^{-2}$**	**5.00**
	50 m	**+ 9°**	**400 Hz**	**$9.32\ 10^{-3}$**	**2.00**
	50 m	**+ 9°**	**400 Hz**	**$5.40\ 10^{-4}$**	**0.12**
	25 m	*- 9°*	*50 Hz*	*$2.50\ 10^{-4}$*	*solution*
	25 m	*- 9°*	*50 Hz*	*$9.34\ 10^{-3}$*	*2.00*
	25 m	*- 9°*	*50 Hz*	*$3.40\ 10^{-4}$*	*0.08*
	25 m	*- 9°*	*50 Hz*	*$1.40\ 10^{-4}$*	*0.03*
	25 m	**- 9°**	**400 Hz**	**$1.20\ 10^{-1}$**	**25.00**
Capture	*10 m*	*+ 18°*	*50 Hz*	*$9.34\ 10^{-3}$*	*2.00*
	10 m	*+ 18°*	*50 Hz*	*$3.40\ 10^{-4}$*	*0.08*
	10 m	*+ 18°*	*50 Hz*	*$1.40\ 10^{-4}$*	*0.03*
	30 m	**0°**	**400 Hz**	**$4.67\ 10^{-3}$**	**1.00**
	30 m	**0°**	**400 Hz**	**$2.36\ 10^{-3}$**	**0.50**
	30 m	**0°**	**400 Hz**	**$1.10\ 10^{-3}$**	**0.23**



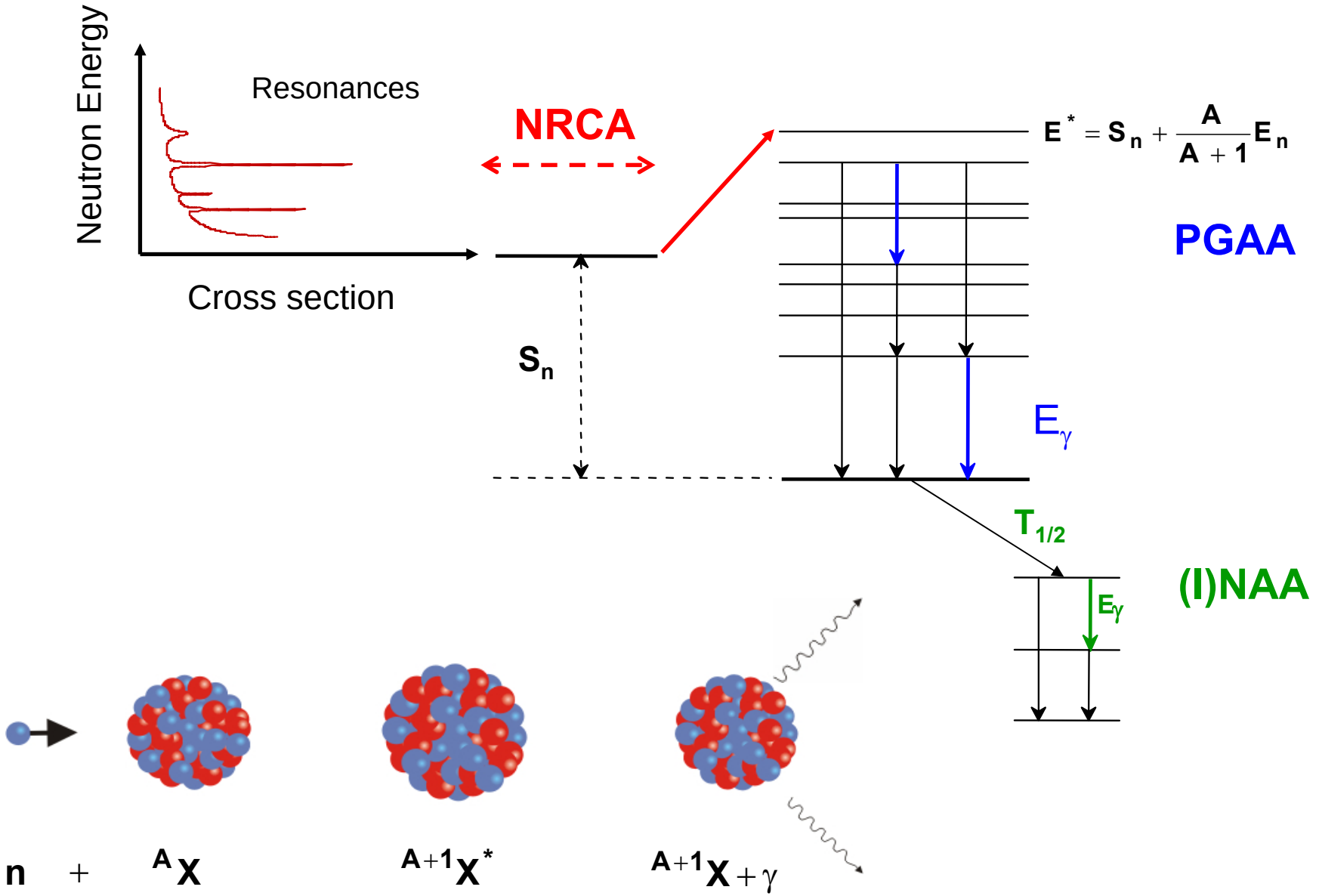
Combine transmission & capture and use samples with different properties

⇒ reduction of bias effects due to:

- Resolution
- Sample properties
- Normalization of capture data

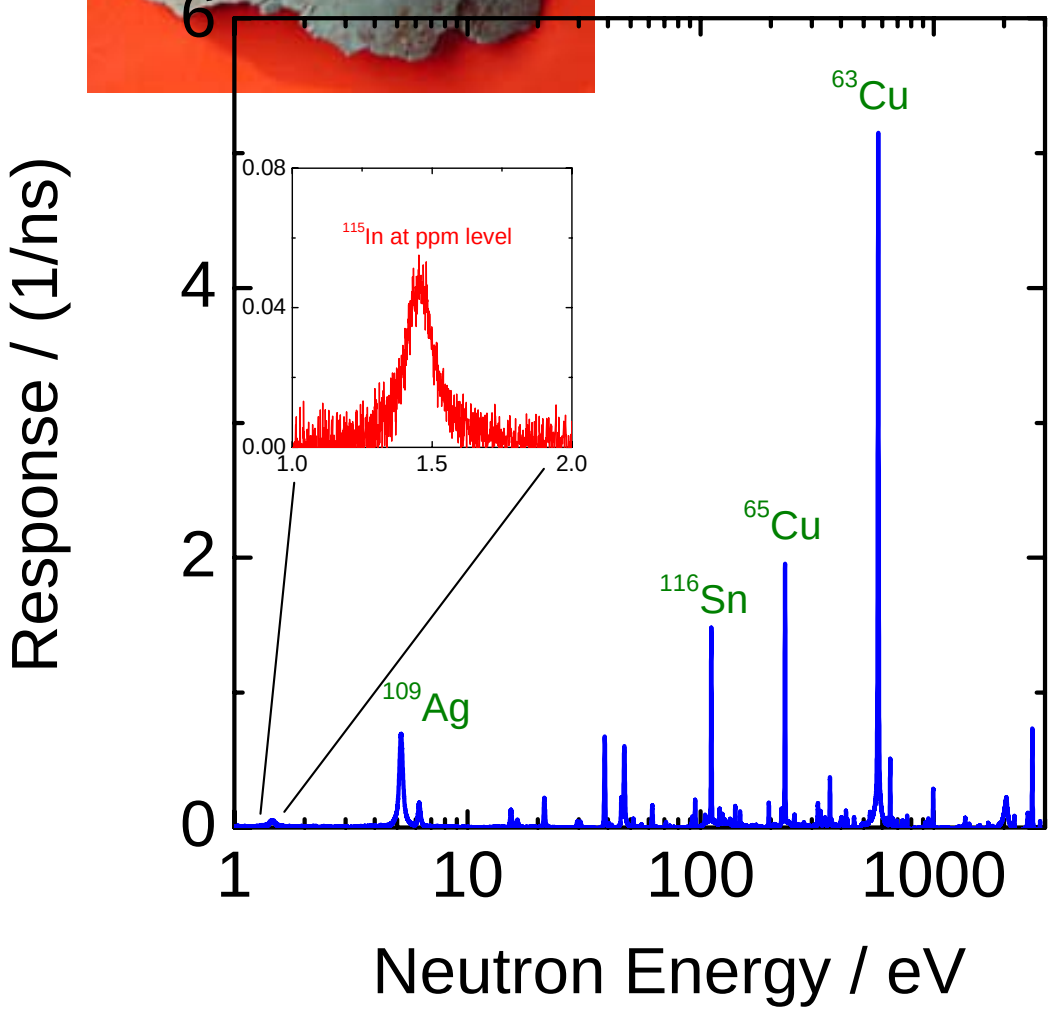
- ***Analysis of cross section data < 1eV***
- ***Final evaluation***
- ***Study impact of new evaluation on results of NAA and interpretation of integral benchmark data***

Neutron Resonance Capture Analysis
NRCA



H. Postma and P. Schillebeeckx, Archaeometry, 2004

NRCA : Elemental Composition of Artefacts



Element	Fractions (%)		Isotope	Resonance (eV)
Cu	**77.76**	**(0.11)**		
			^{63}Cu	579.0
			^{65}Cu	230.0
Sn	**20.85**	**(0.10)**		
			^{112}Sn	94.8
			^{116}Sn	111.2
			^{117}Sn	38.8
			^{118}Sn	45.7
			^{119}Sn	222.6
			^{120}Sn	427.5
			^{122}Sn	1756.0
			^{124}Sn	62.0
As	**0.34**	**(0.01)**		
			^{75}As	47.0
Sb	**0.196**	**(0.021)**		
			^{121}Sb	6.24
			^{123}Sb	21.4
Ag	**0.090**	**(0.01)**		
			^{107}Ag	16.3
			^{109}Ag	5.2
Fe	**0.770**	**(0.09)**		
			^{56}Fe	1147.4
In	**0.0061**	**(0.0003)**		
			^{115}In	1.46

m_{NRCA} = 13.0 (0.5) g
m_{weigth} = 13.25 g

NRCA : Characterisation of Reference Materials
^{103}Rh metal disc

	Natural abundance (wt %)	Relative Amount (wt %)	
^{103}Rh	100	99.5137	
^{181}Ta	99.988	0.0337	(0.0029)
^{191}Ir	37.3	0.0870	(0.0033)
^{193}Ir	62.7	0.1478	(0.0076)
^{182}W	26.3	0.0552	(0.0027)
^{183}W	14.3	0.0302	(0.0028)
^{186}W	28.6	0.0613	(0.0025)
^{197}Au	100	0.0059	(0.0011)

$\Rightarrow$ Impurities contribute for 0.5 % to the observed count rate in the thermal energy region

^{103}Rh(n_{th},γ) cross section is requested with an accuracy < 2%