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Nat Pb neutron scattering cross section measurement & data analyze

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Why nuclear data

Nuclear Data Libraries

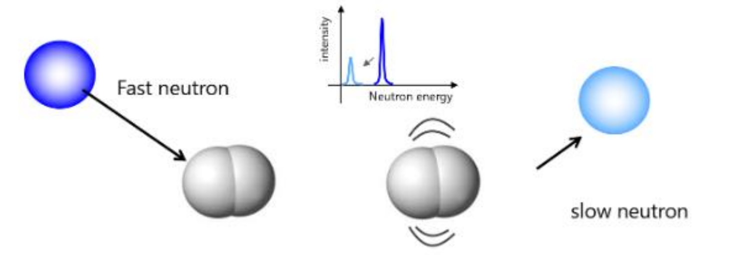
Nuclear Reactor Design

- Gen-IV detectors (Mainly fast reactors)
- Fusion reactors development

Fast neutron induced reaction cross-section

Inelastic scattering

- Fast neutron ~ several MeV (Kinetic energy loss)
- γ ~ 1-2MeV



Materials interested in

Material	Isotope	Gamma Energy 1 (MeV)	Gamma Energy 2 (MeV)	Gamma Energy 3 (MeV)
Iron	56Fe	0.847	1.238	2.612
Stainless Steel (Iron)	56Fe	0.847	1.238	2.612
Stainless Steel (Nickel)	58Ni	1.454	1.608	2.311
Stainless Steel (Chromium)	52Cr	1.434	2.306	
Nickel	58Ni	1.454	1.608	2.311
Zirconium	90Zr	2.186	2.231	
Aluminum	27Al	0.843	1.014	1.779
Titanium	48Ti	0.984	1.312	1.983
Copper	63Cu	0.667	1.347	2.231
Lead	208Pb	0.583	0.86	2.615
Tungsten	184W	0.111	0.324	0.684

Target choice

SS in nuclear structure

- No measurement in the past
- Super practical
- Achievable sample

Pure element

- Clear spectrum
- Easier with simulation & analysis (Maybe)

Isotopes in SS

Iron

- ^{54}Fe ^{56}Fe ^{57}Fe ^{58}Fe

Chromium

- ^{50}Cr ^{52}Cr ^{53}Cr ^{54}Cr

Nickel

- ^{58}Ni ^{60}Ni ^{61}Ni ^{62}Ni ^{64}Ni

Molybdenum

- ^{92}Mo ^{94}Mo ^{95}Mo ^{96}Mo ^{97}Mo ^{98}Mo ^{100}Mo

Manganese

- ^{55}Mn

Cobalt

- ^{59}Co …

Target choice

SS in nuclear structure

- No measurement in the past
- Super practical
- Achievable sample

Rejected

Pure element

- Clear spectrum
- Easier with simulation & analysis (Maybe)

Accepted

Why Pb important?

High priority in request

- Enhance the accuracy with which reactor integral parameters may be estimated
- Impact economic and safety margins

ID	Target	Reaction	Quantity	Energy range	Cov Field	Date
18H	92-U-238	(n,inl)	SIG	65 keV-20 MeV	Y Fission	11-SEP-08
34H	26-FE-56	(n,inl)	SIG	0.5 MeV-20 MeV	Y Fission	12-SEP-08
41H	82-PB-206	(n,inl)	SIG	0.5 MeV-6 MeV	Y Fission	15-SEP-08
42H	82-PB-207	(n,inl)	SIG	0.5 MeV-6 MeV	Y Fission	15-SEP-08

Table 1: NEA Nuclear Data High Priority Request List, HPRL - (n,inl) [2]

GEN-IV & Breeder material

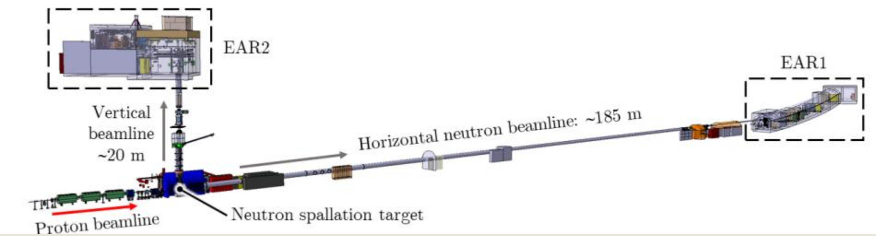
- Small Modular lead-cooled reactor
- Lead-Cooled fast reactor
- Lead-lithium alloy as breeder material
- ...

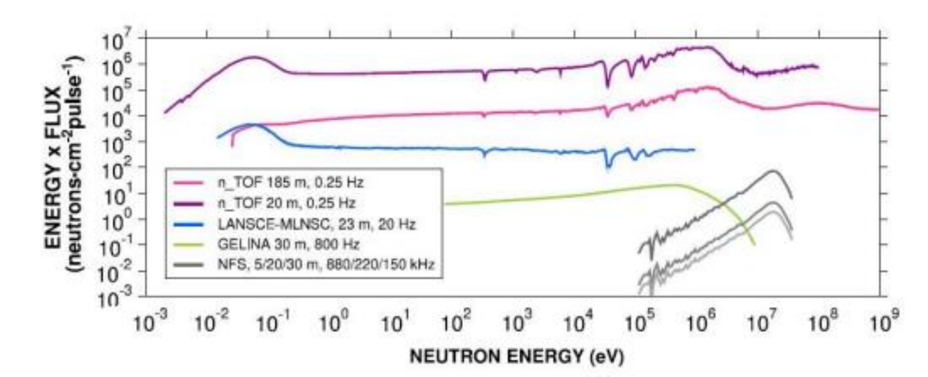
n_ToF facility in CERN

- High maximum flux
- Narrow energy resolution
- Large range of neutron energy

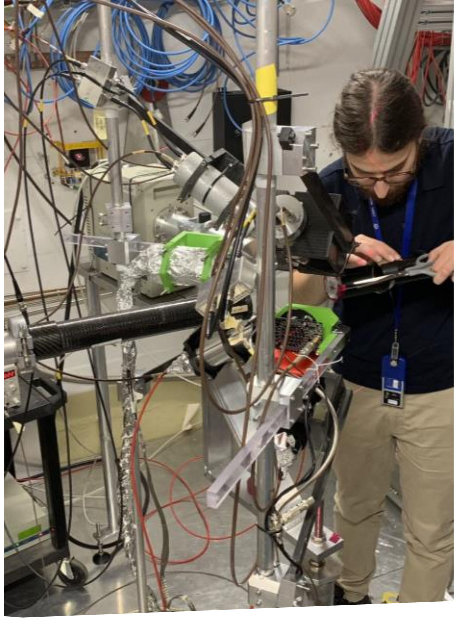
From meV to GeV

$$E_n(\text{eV}) = \frac{1}{2} m_n v^2 = \left(\frac{72.2983 \cdot L(\text{m})}{t_{det}(\mu\text{s}) - t_{prod}(\mu\text{s})} \right)^2$$



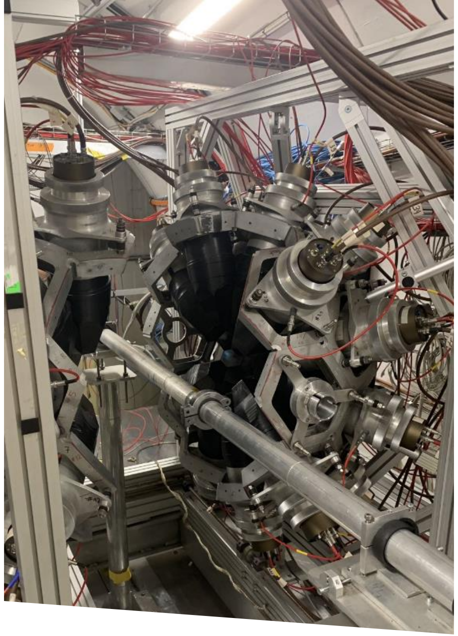


Neutron Escape Line

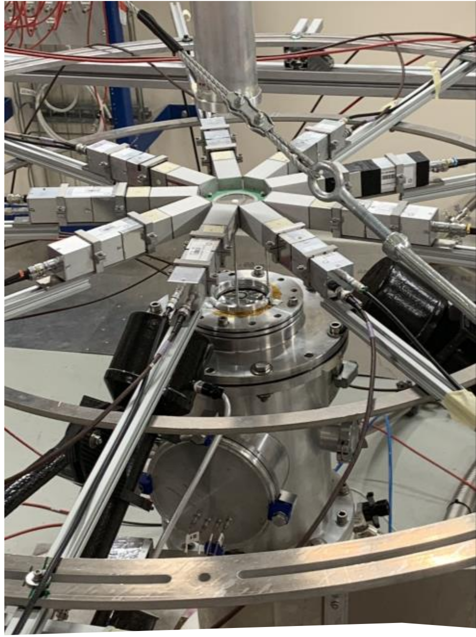


EAR1

$LaBr_3$ & HPGe detectors



The Total Absorption Calorimeter (TAC)



EAR2

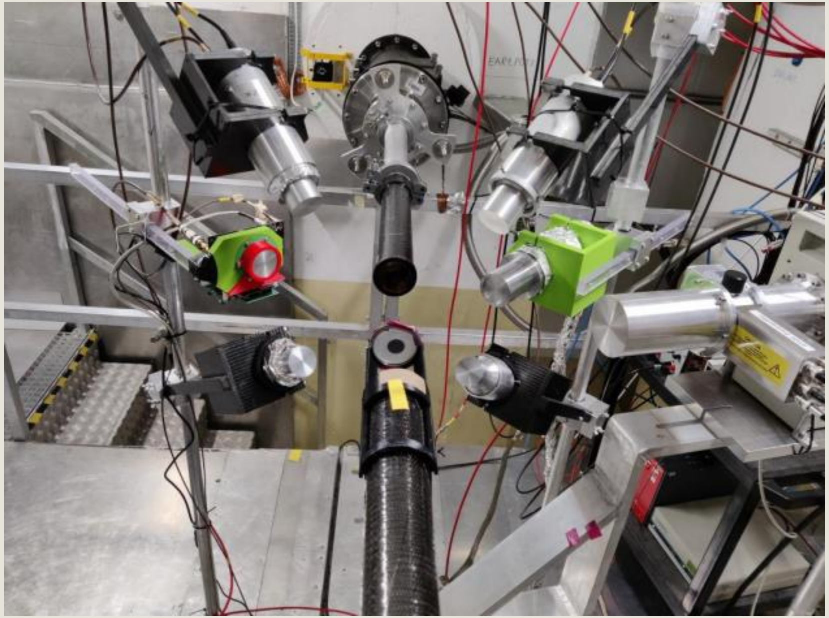
C6D6 & sTED detectors

EAR1 & EAR2

First run in May – ^{24}Mg(n,inl)

Detectors tested:

2 X LaBr3 (Ce) INFN :
• PMT Hamamatsu R6231 readout with active voltage dividers
• 1.5" x 1.5", 1.5" x 2" crystals
2 X LaBr3 (Ce) University of Manchester(UoM):
• PMT Hamamatsu R6231 readout with passive VD
• 1.5" x 1.5" crystals
2 X LaBr3 (Ce) IFIN-HH:
• 1 gated PMT readout &1 gated SiPM readout
• 1.5" x 2" crystals HPGe Mirion
• Gated preamp

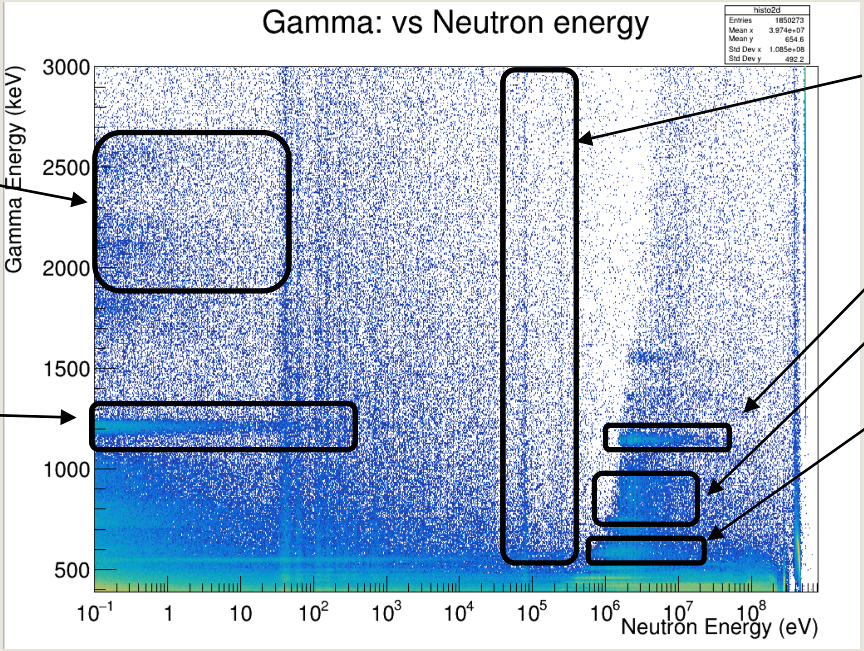


Neutron inelastic cross section measurement

UNIVERSITY of York

Alpha from La containments

La decay line



Mg absorption resonances

Inelastic scatter line of ^{24}Mg

Inelastic scatter line of ^{25}Mg

Inelastic scatter line of La & Br

Overall Spectrum of ^{24}Mg (IFIN-HH) $LaBr_3$(Ce) Detector, May 2024

Improvements & Preliminary Data Analyze ：

Detector development can be made to gain better resolution of energy (like PMT & SiPM)

Shielding can help to reduce ringing effect

Considering gamma flash

Calibration

Pulse Shape Analyze

Charge Integration Method

Background Subtraction

…

Thanks for your listening

Reference

Cross section and neutron angular distribution measurements of neutron scattering on natural iron https://doi.org/10.1103/PhysRevC.99.024601

Negret A, Borcea C, Dessagne P, Kerveno M, Olacel A, Plompen A, Stanoiu M. Cross-section measurements for the 56Fe(n, xnγ) reactions. PHYSICAL REVIEW C 90; 2014. p. 034602-1 - 034602-15. JRC91536

McConchie, Seth, et al. Assessment of modeling and nuclear data needs for active neutron interrogation. No. ORNL/TM-2021/1900. Oak Ridge National Lab.(ORNL), Oak Ridge, TN (United States), 2021.

n_ToF collaboration. Measurement of the 238U(n,γ) cross section up to 80 keV with the Total Absorption Calorimeter at the CERN n_TOF facility, PHYSICAL REVIEW C, ISSN 2469-9985, 96, 2017, p. 064601, JRC110713.

…

Thanks to Nuclear Group & n-ToF collaboration

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Backup

Gamma flash

Effects

- Detector saturation
- Baseline shifts
- Dead time

How it generated

- Thought to come with neutron beam at first
- Then it is proved that it comes from decay of neutron pions

Pb energy level

Pb-206

- https://www.nndc.bnl.gov/nudat3/getdataset.jsp?nucleus=206Pb&unc=NDS

Pb-207

- https://www.nndc.bnl.gov/nudat3/getdataset.jsp?nucleus=207Pb&unc=NDS

Pb-204

- https://www.nndc.bnl.gov/nudat3/getdataset.jsp?nucleus=204Pb&unc=NDS

Pb-208

- https://www.nndc.bnl.gov/nudat3/getdataset.jsp?nucleus=208Pb&unc=NDS

Research Plan

Detector development

Advanced LaBr3 detector with SiPM development
By the end of 2024

Experiment design

Hand in the experiment proposal to CERN
Before October of 2024

Simulation for experiment

Simulate the potential environment for the experiment

Experiment & Preliminary data analyse

Calibration – Background subtraction – pulse shape analyse - …
Expected during the running year of 2025

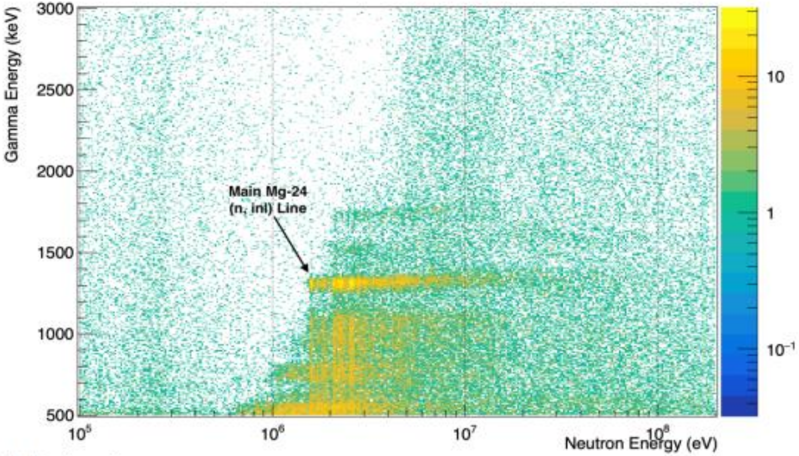
Data analyse

TBC

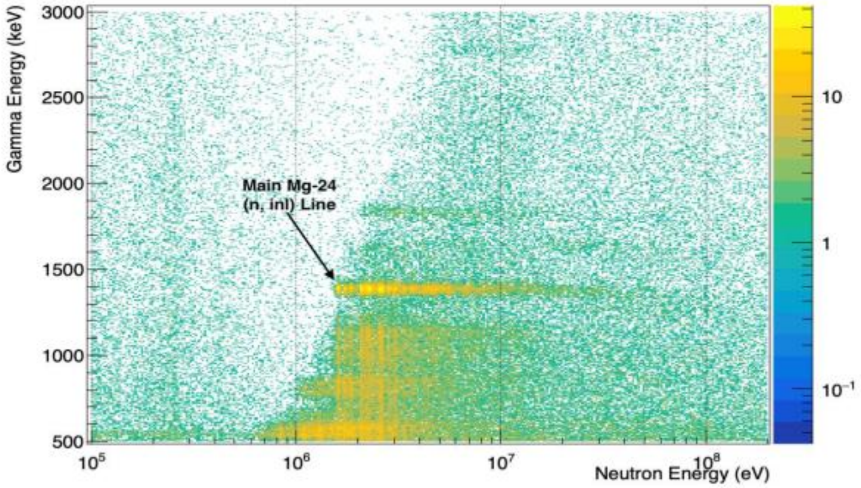
Current state of data

- IFIN-HH detector performs best – smallest ringing and very little gain drift (if any).
- INFN detector has strongest drift, UoM has worst ringing.
- As would be expected, ringing is worse in dedicated vs parasitic pulses.

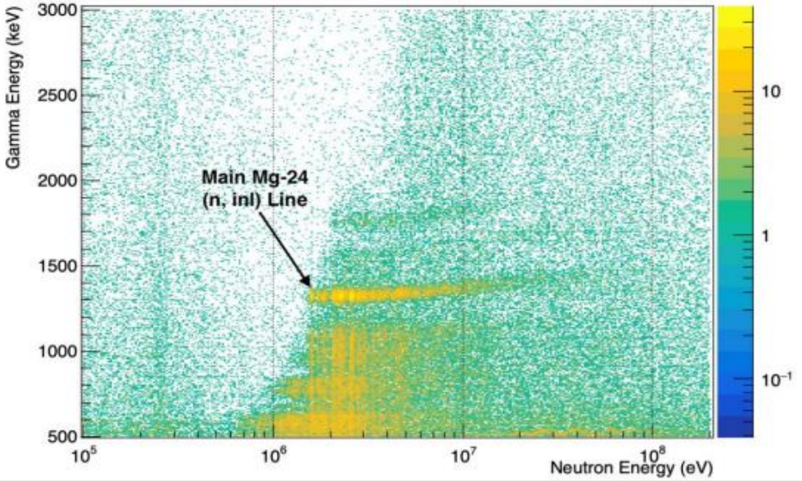
UoM Detector Gamma Energy vs Neutron Energy 5.1%



IFIN-HH Detector Gamma Energy vs Neutron Energy 3.5%



INFN Detector Gamma Energy vs Neutron Energy 3.8%



SMR – lead cooled

- https://www.sckcen.be/en/expertises/nuclear-systems/lead-cooled-fast-reactor-belgium/small-modular-reactor-smr