Measurement of high-energy gamma-rays accompanied by $^{235}U(n_{th},f)$

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EXILL 2015


Tokai Campus, JAEA
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J-PARC
Tandem facility

Experimental Research Program at the JAEA Nuclear Physics Group

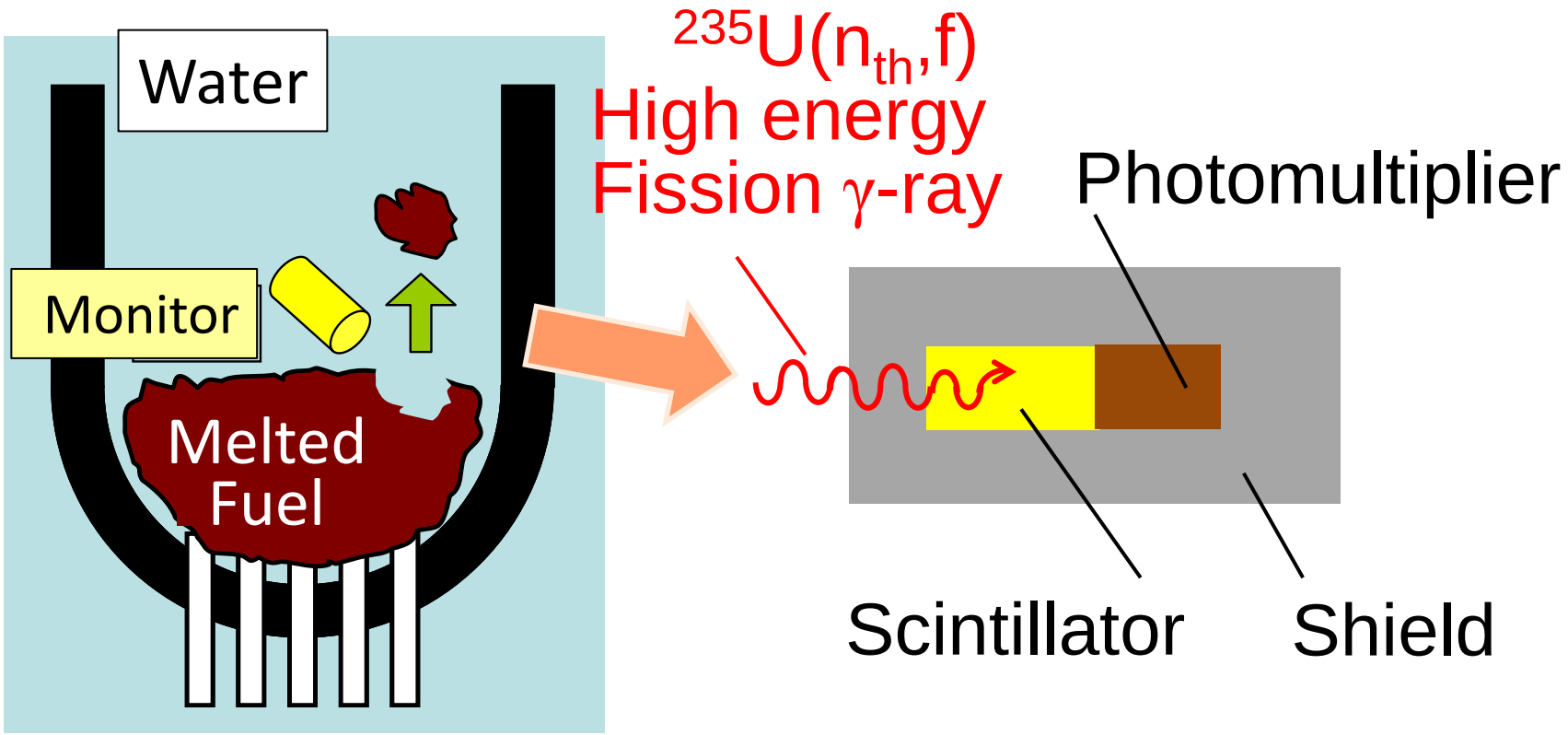
- Nuclear fission (JAEA tandem, J-PARC n-TOF, …)
- Reaction mechanism for heavy-element synthesis (JAEA tandem)
- Surrogate and multi-nucleon transfer reaction study (JAEA Tandem)
- Search for the heaviest N=Z nucleus beyond ^{100}Sn (JAEA Tandem + RMS)
- Structure study of neutron-rich nucleus (CERN-ISOLDE, RIKEN-RIBF,…)
- Fukushima issues

High-energy γ-rays accompanied by fission

- FUKSHIMA Issues
- A surveillance detector to monitor criticality and power.
- Nuclear fission and deexcitation of fission fragments.
- $LaBr_3$(Ce) detector
- Experimental Setup

FUKUSHIMA Atomic Power Plants

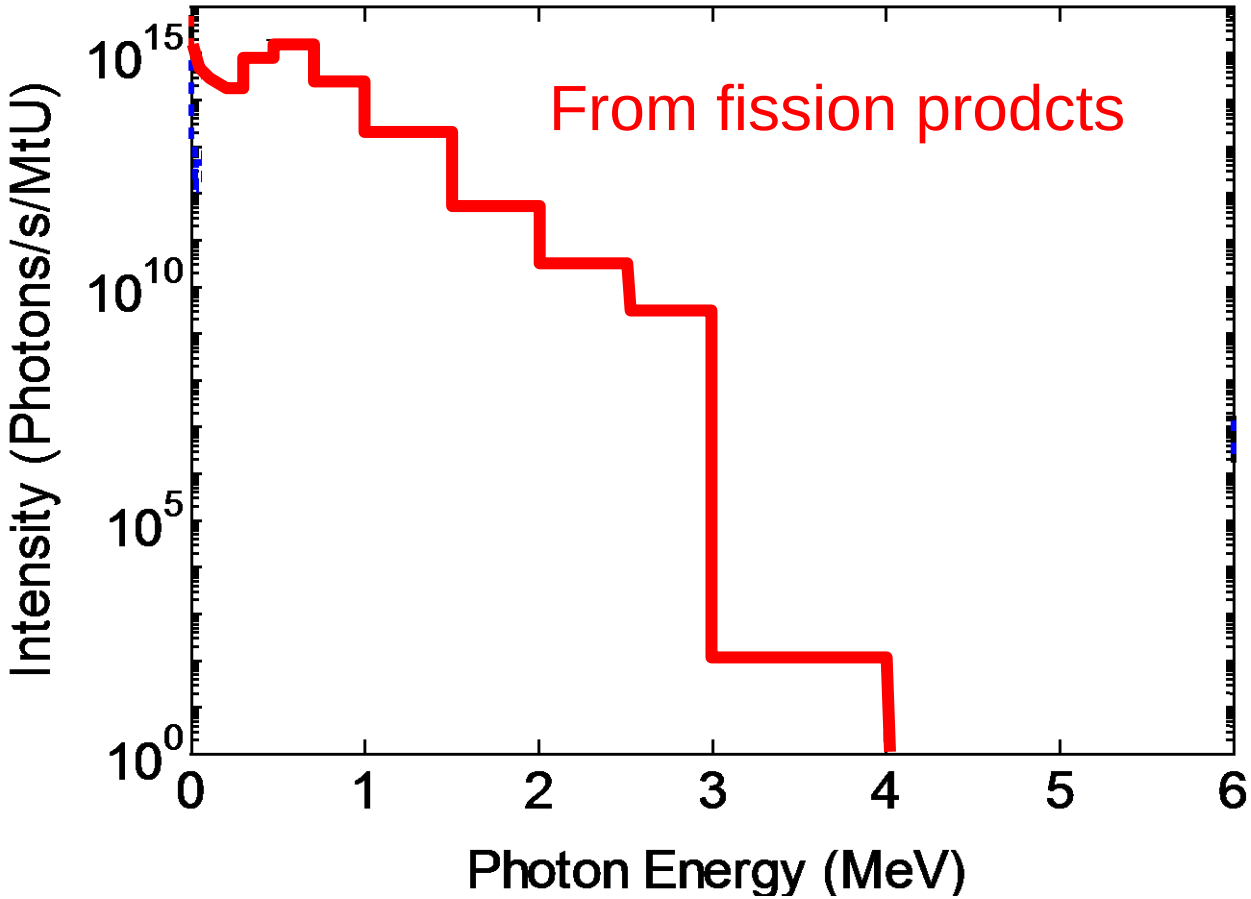
Surveillance Detector for criticality and Power



Fission rate must be measured in a strong radiation environment

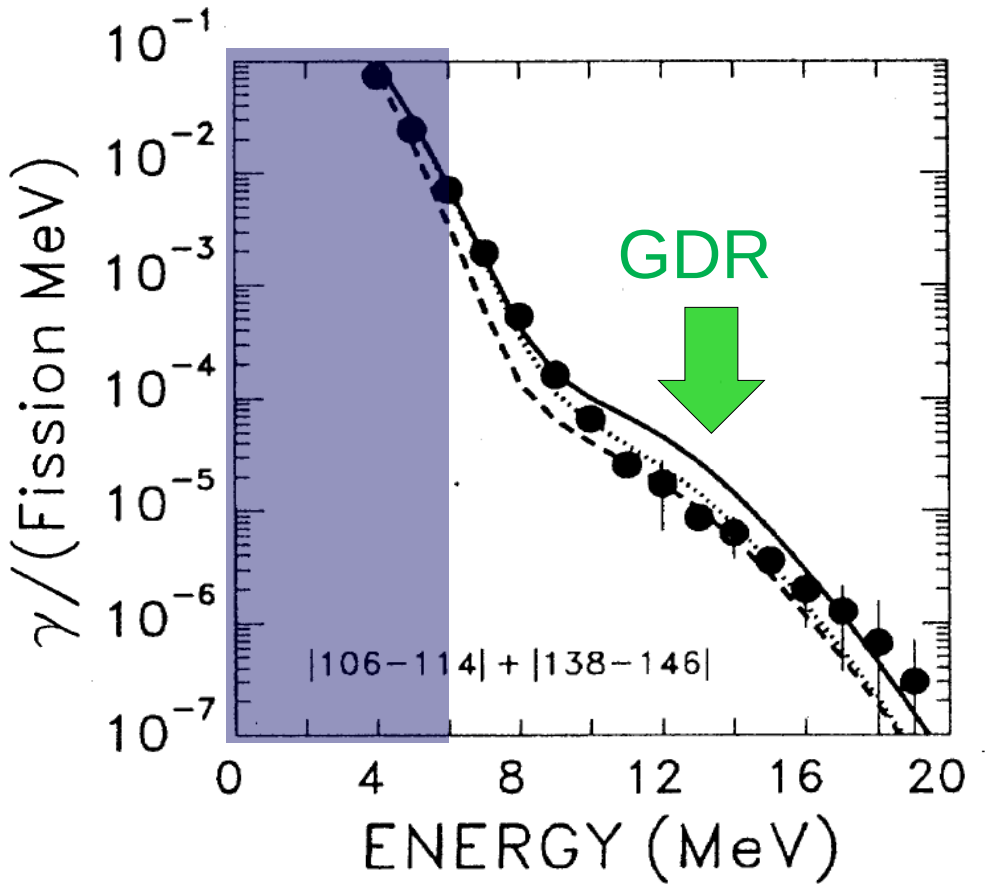
Energy Spectrum from Spent Nuclear Fuels

After 10 years has past



ORIGEN Code
From Suyama, JAEA

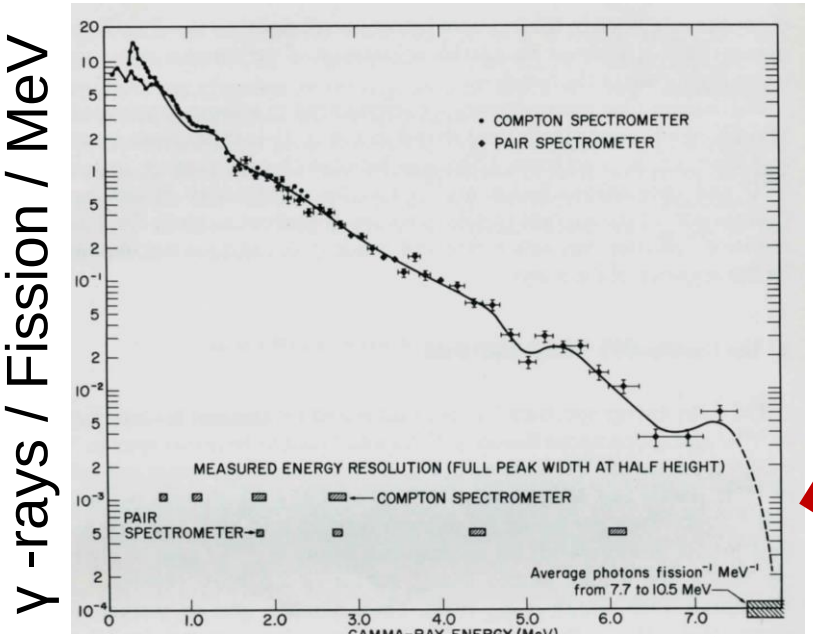
Fission gamma-rays spectrum ^{252}Cf (sf)



H. Van der Ploeg *et al.*, Phys. Rev. C, **52** (1995) 1915.

Gamma-ray spectrum for $^{235}U(n_{th}, f)$

$^{235}U(n_{th}, f)$



Up to 7 MeV

Need to extend measurement to high energy region

"*Nuclear Fission*", Robert Vandenbosch, J.R. Huizenga, Academic Press 1973

Nuclear Fission

Fissionig nucleus

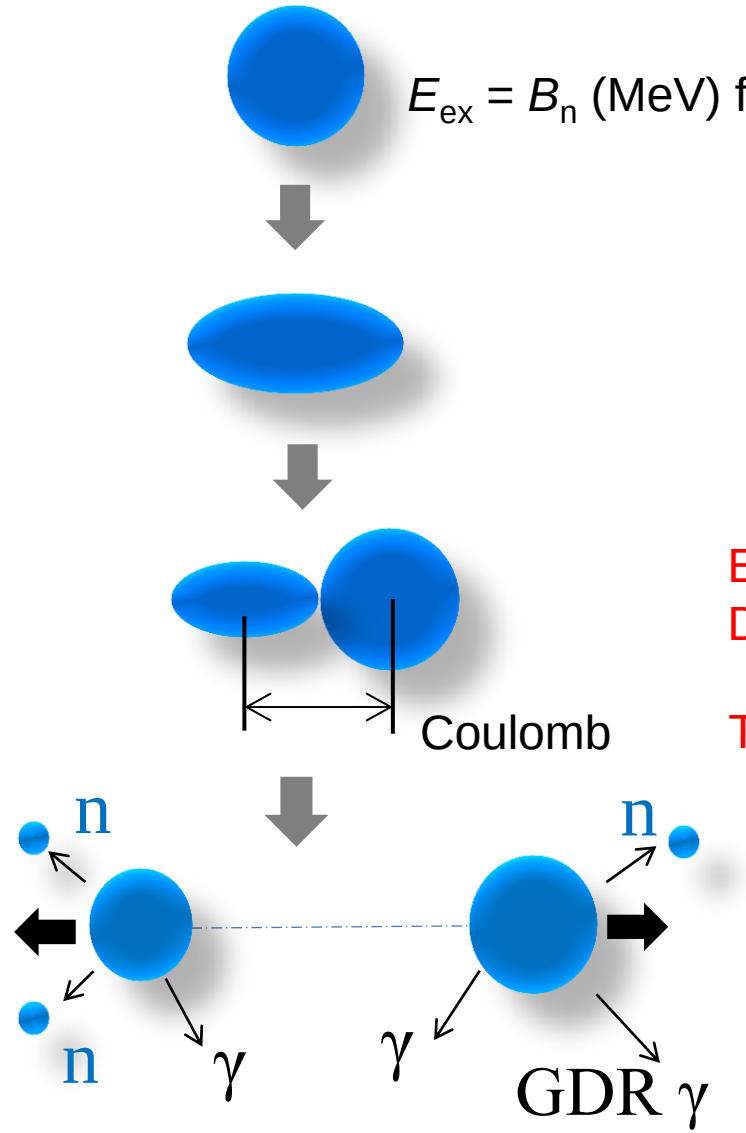
$E_{ex} = B_n$ (MeV) for Thermal-neutron induced fission

Deformation

Scission

Energy release (fission Q-value)
Deformed Shape

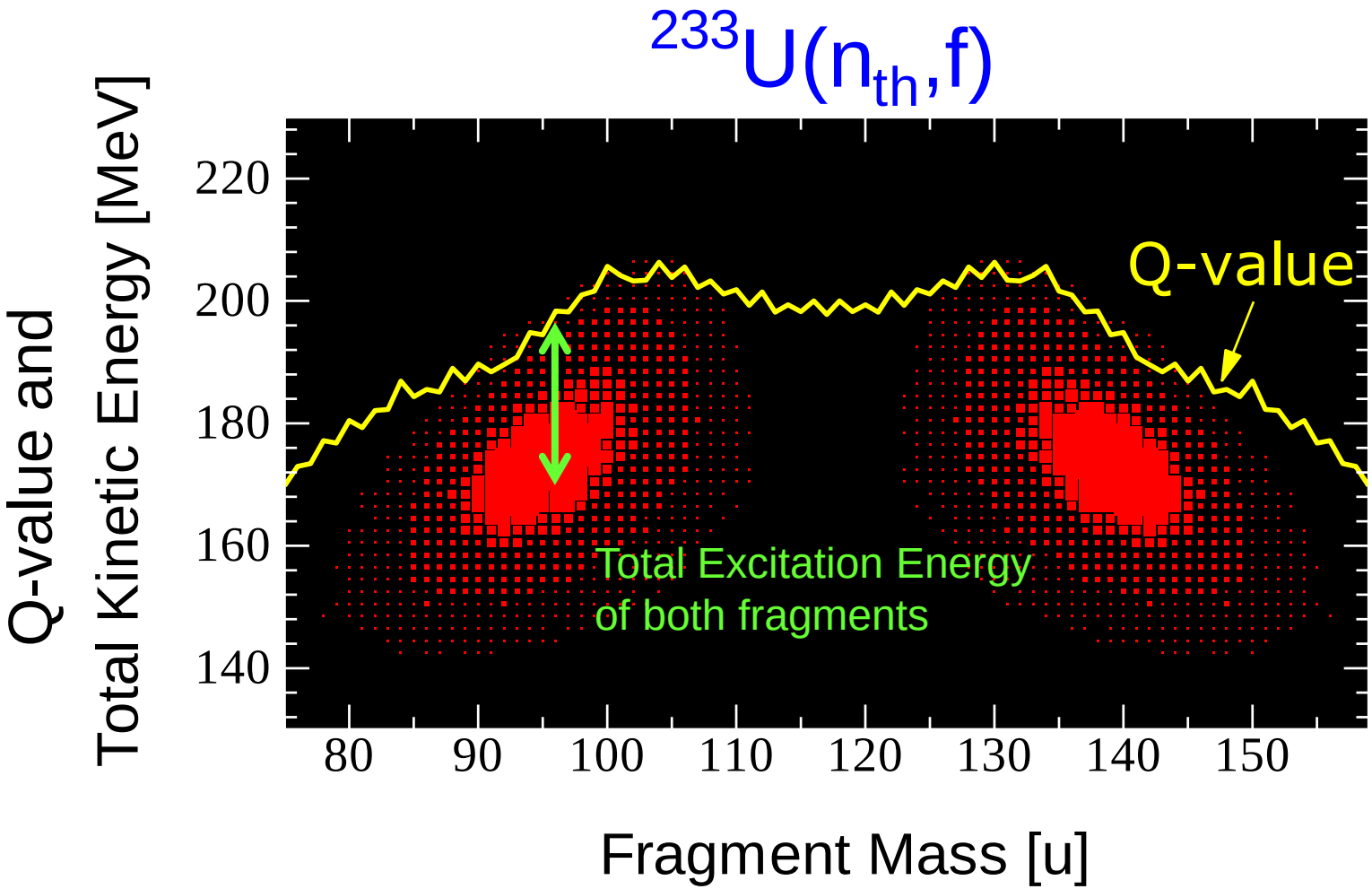
Total Kinetic Energy of Fragments



Neutron and gamma emission

Neutron-rich Nuclei

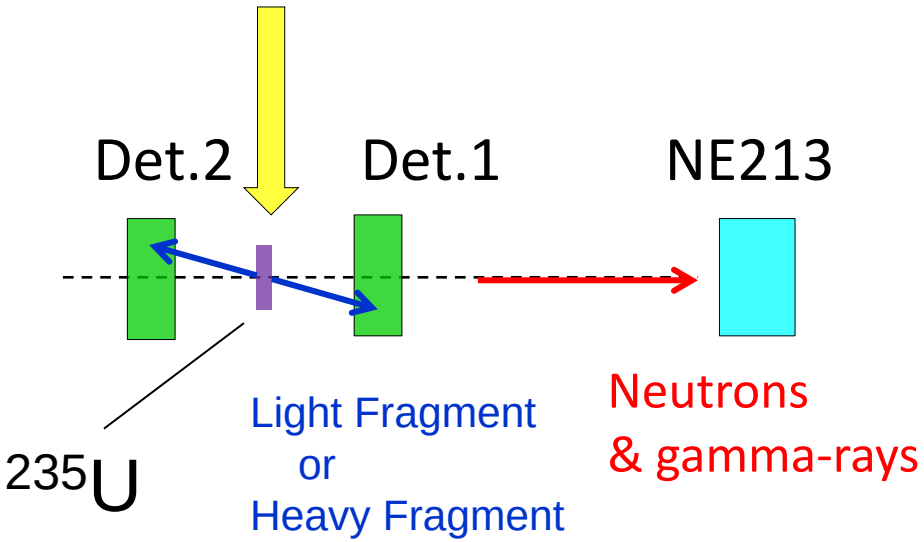
Fission Fragment Yield

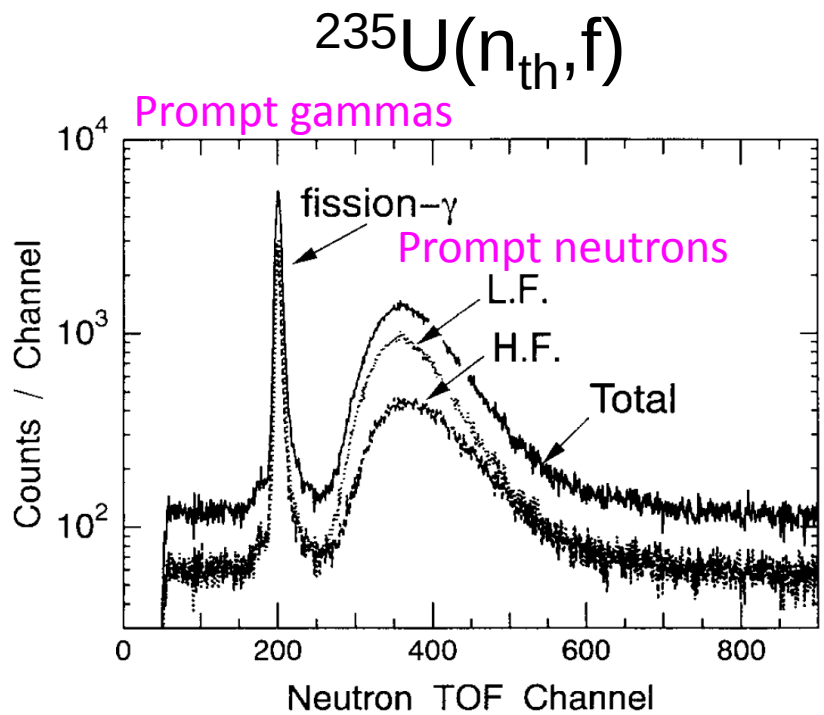


K. Nishio et al., J. Nucl. Sci. Technol. **35** (1998) 631.

Prompt Neutrons from Fission Fragment

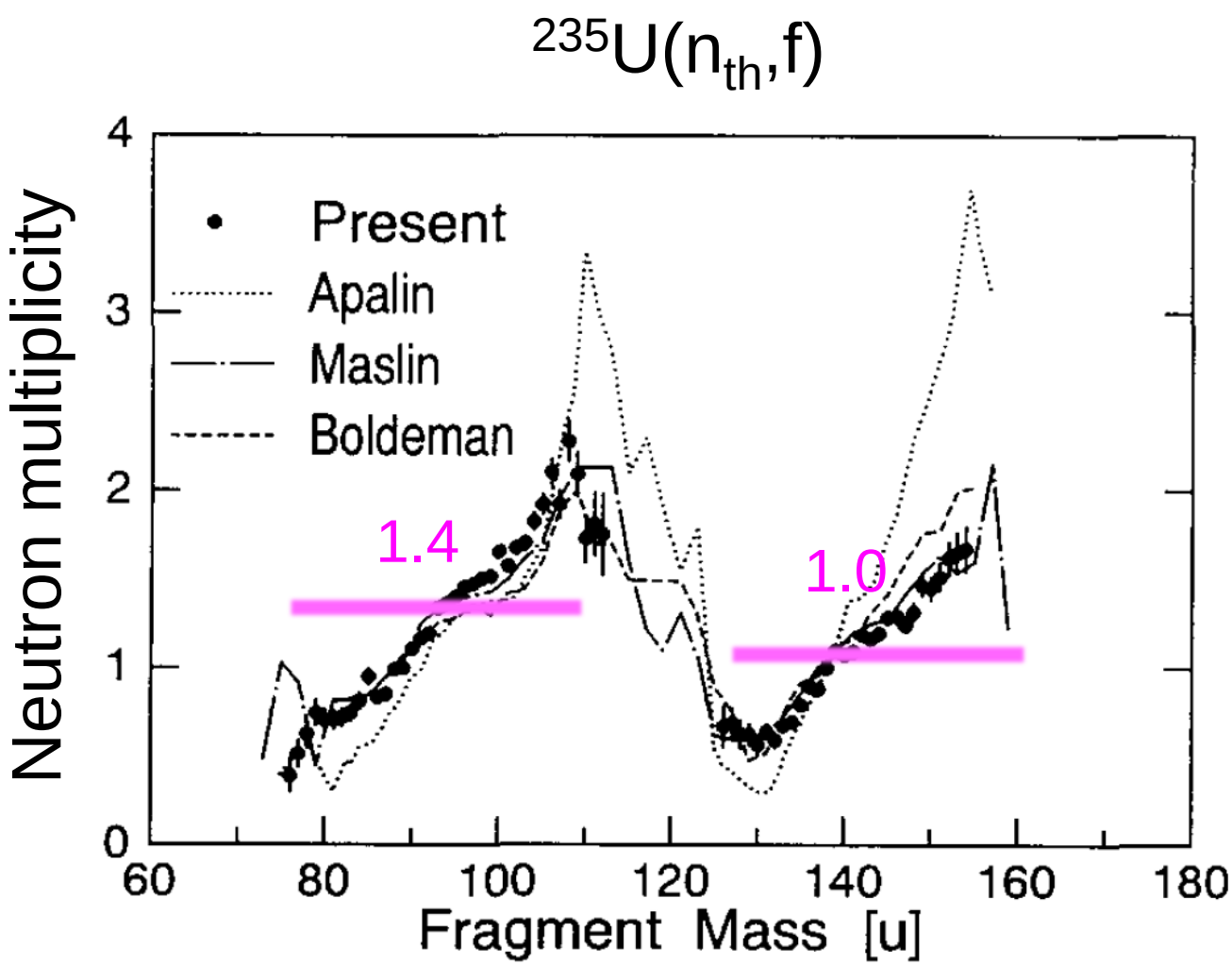
Neutrons from the Kyoto University Reactor





K. Nishio et al., Nucl. Phys. A632 (1998) 540.

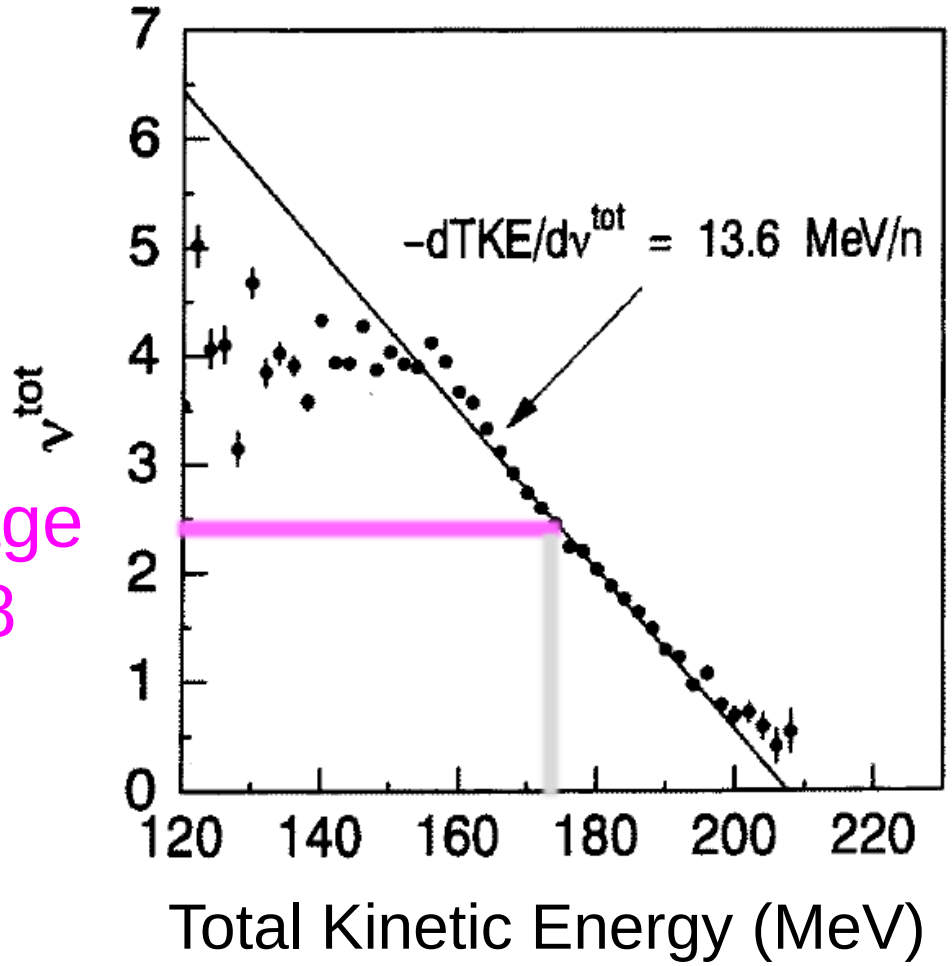
Neutron multiplicity from individual fragments



Large Excitation Energy

Total = 2.4

Total neutron multiplicity as function of TKE

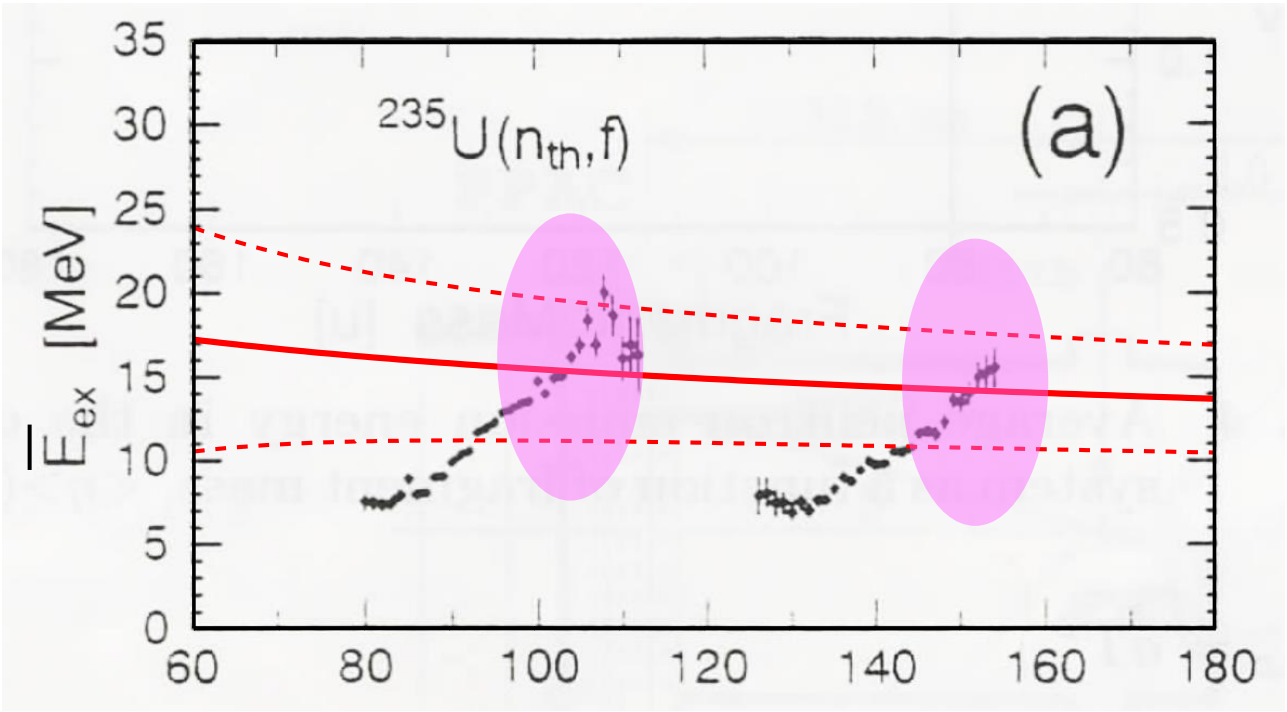


Average = 2.48

$^{233}U(n_{th},f)$

Average Excitation energy of fission fragments for $^{235}U(n_{th},f)$

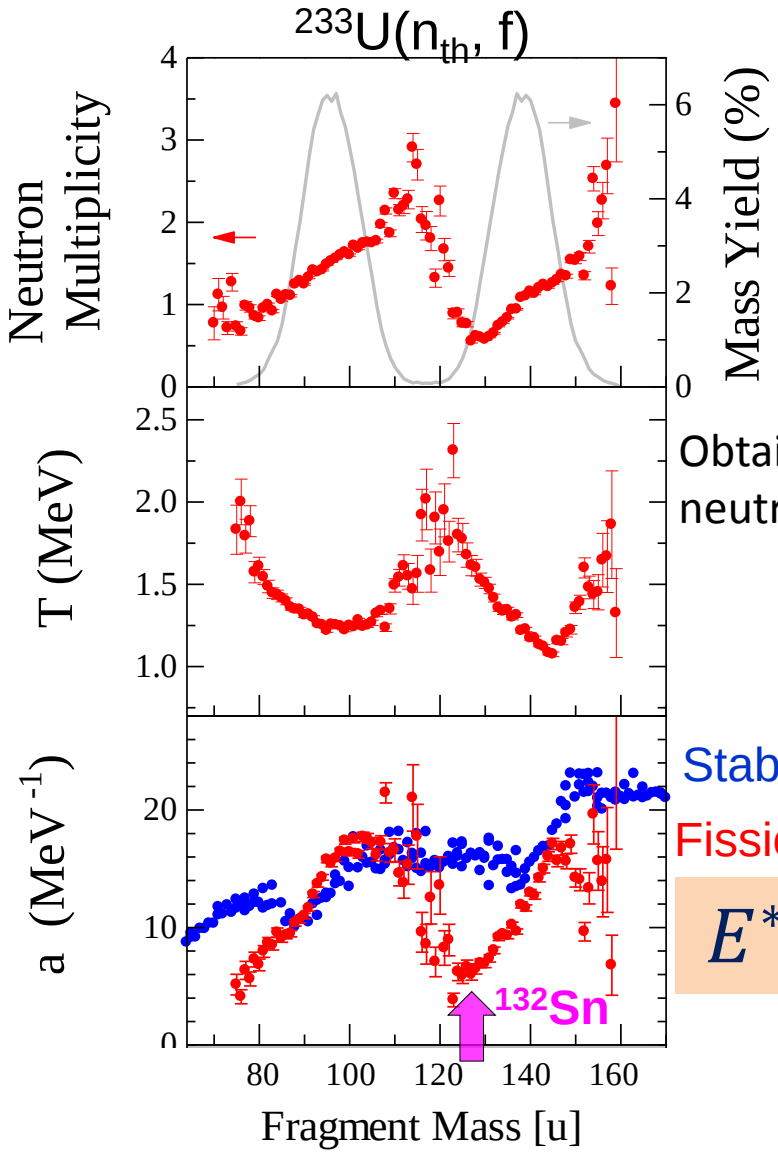
$$E_{GDR} = 18.0A^{-1/3} + 25.0A^{-1/6}$$



Fragment mass (u)

Data from K. Nishio et al., Nucl. Phys. A632 (1998) 540.

Level Density Parameters

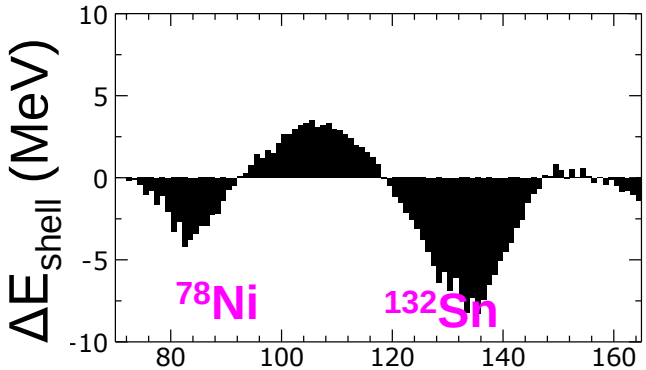


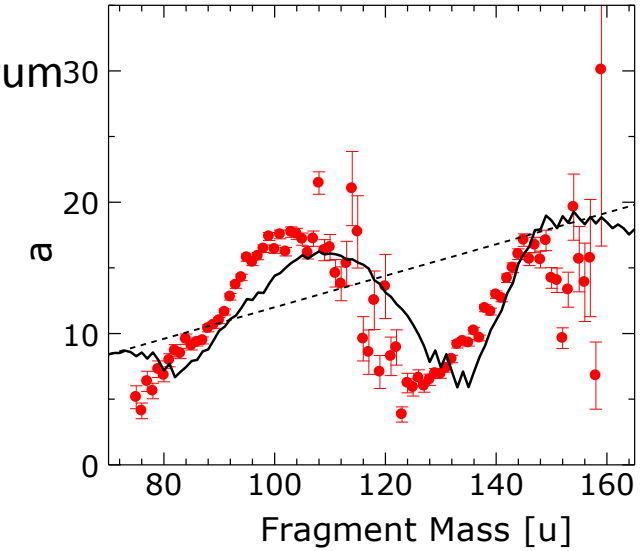
Obtained from neutron-energy spectrum

Stable Nuclei

Fission Fragments

$$E^* = aT^2$$

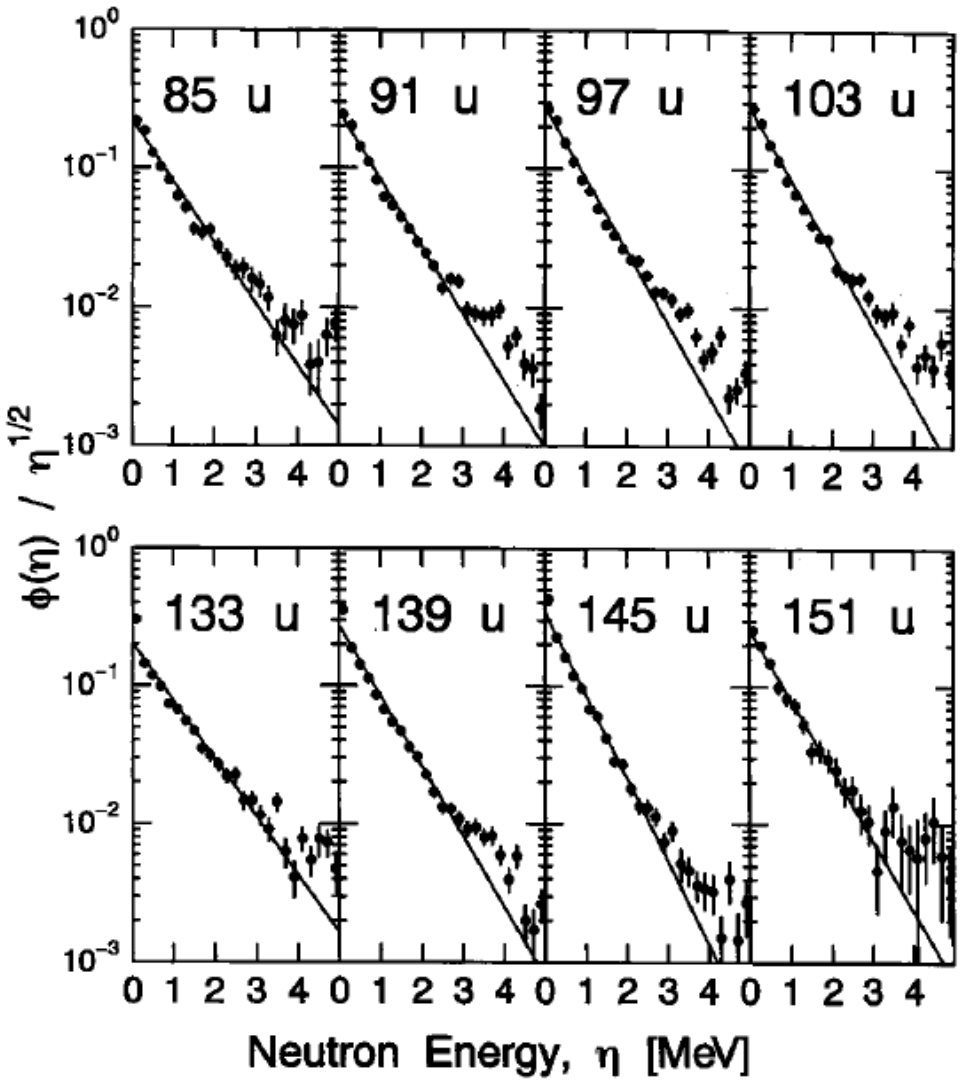




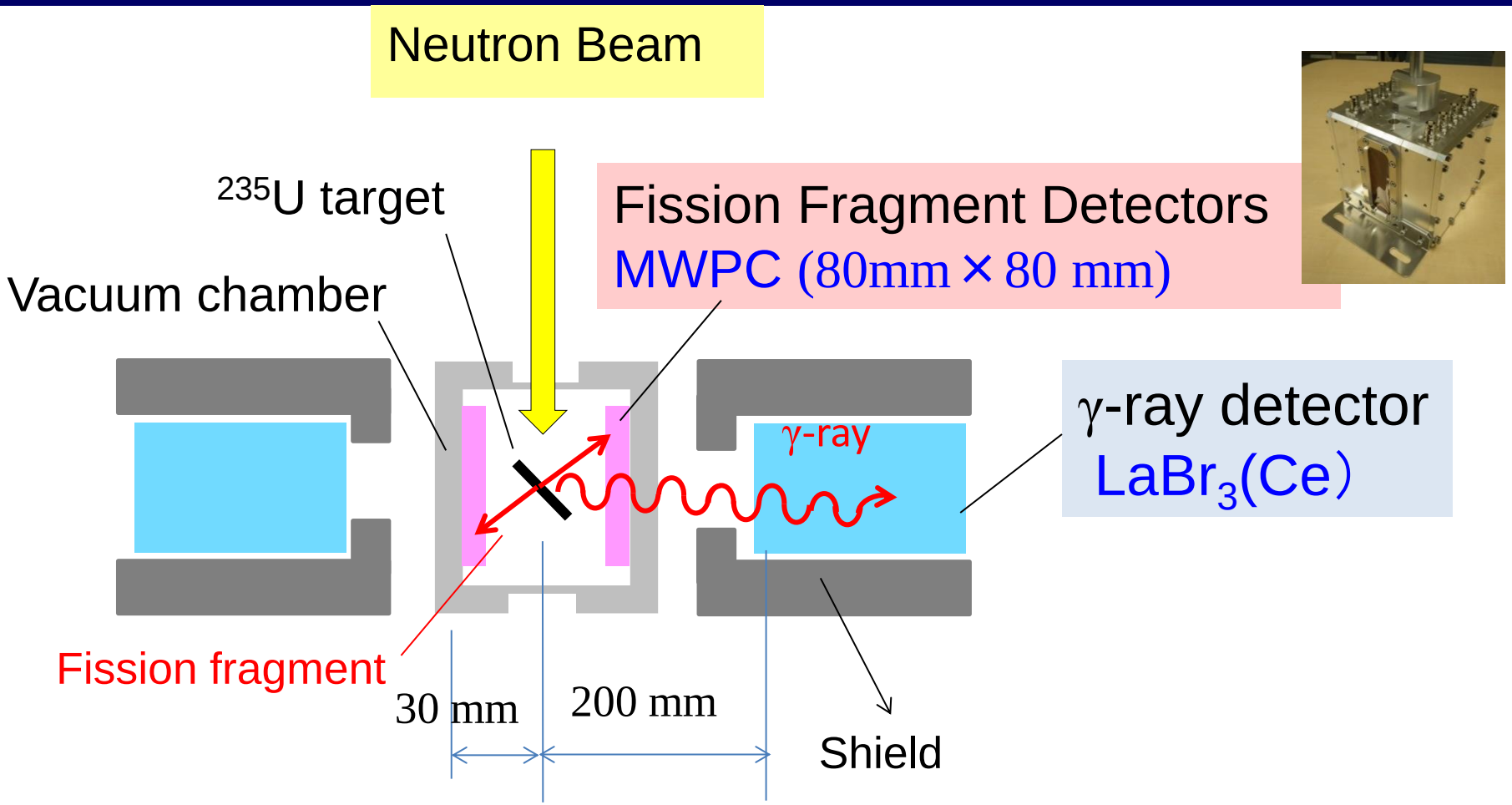
$$a = \bar{a}\left\{1 + \frac{1 - \exp(E^*/E_D)}{E^*}\,\Delta E_{Shell}\right\}$$

Neutron-energy spectrum from individual fragment

$^{233}U(n_{th},f)$



Setup to measure fission γ–rays in $^{235}U(n_{th},f)$

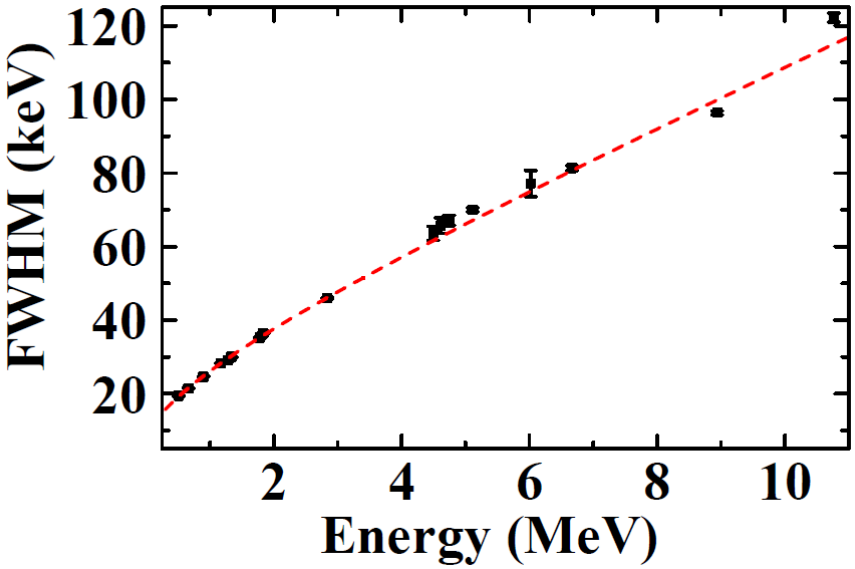


Data for fission neutrons can be also obtained.

$LaBr_3$(Ce) detector

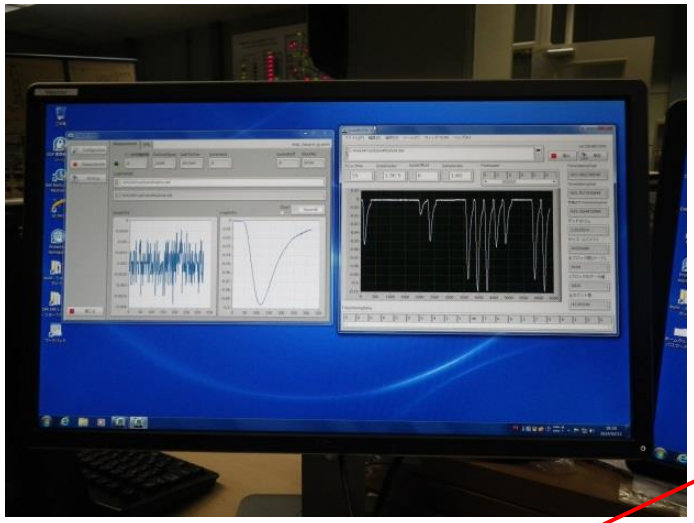
Diameter 4” x Length 5”

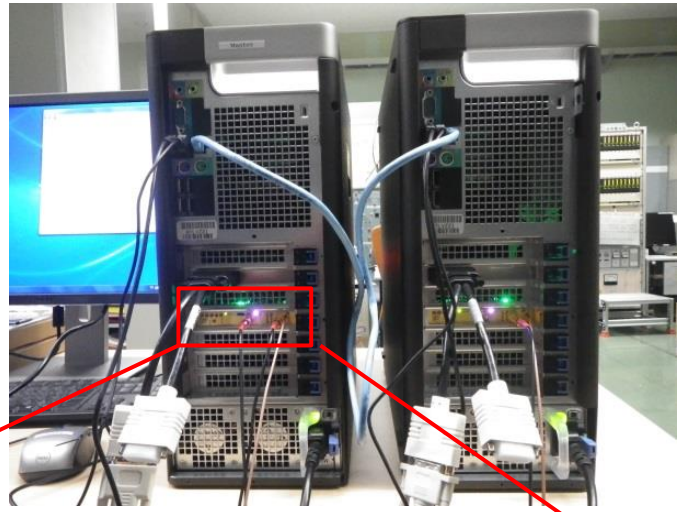
(1) High Efficiency
(2) High-resolution
(3) Fast timing properties



H. Makii et al., submitted to Nucl. Instr. Meth. A

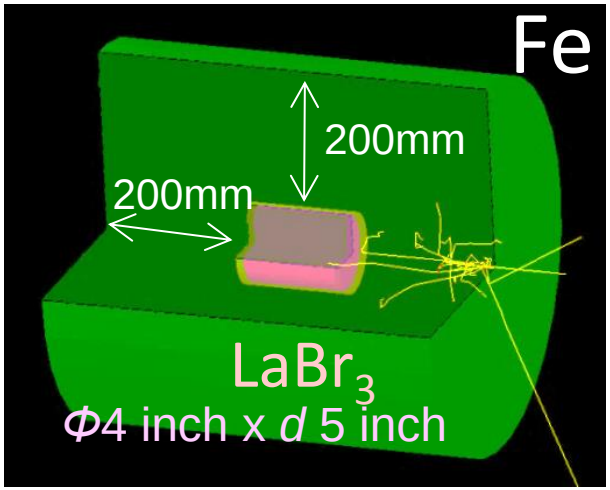
Digital Data Taking

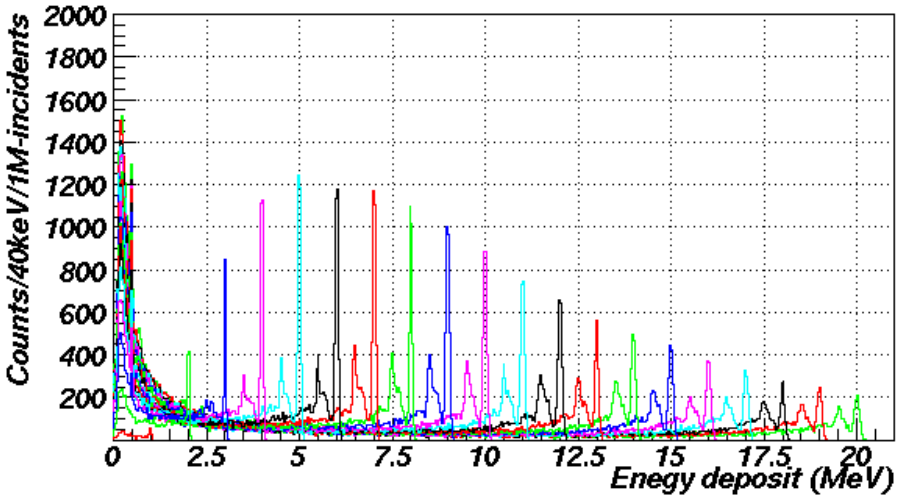


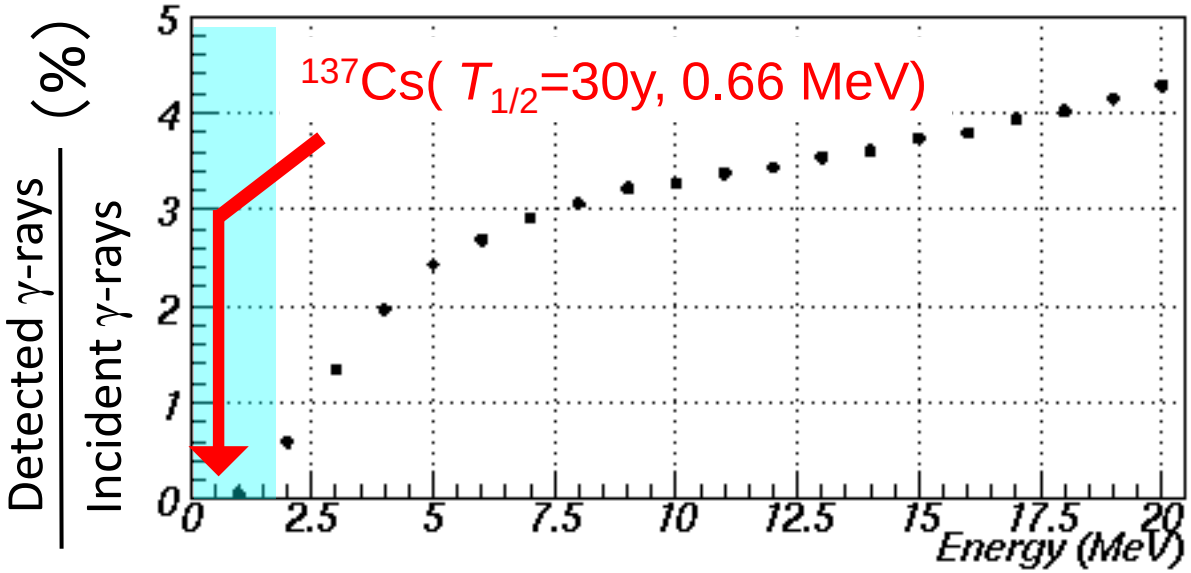


Agilent U5303A
1.6 GHz sampling

Surveillance Detector







Summary

- A surveillance detector to monitor criticality of melted fuel debris at the FUKSHIMA power plant is proposed.
- Detection of high-energy γ-rays in $^{235}U(n_{th},f)$.
- Developed a large volume $LaBr_3(Ce)$ detector and setup

→ Supported by Government Fund

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