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Tsinghua University

Contrabands detection with a low energy electron linac driven photoneutron source

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IAEA Headquarters | Vienna, Austria
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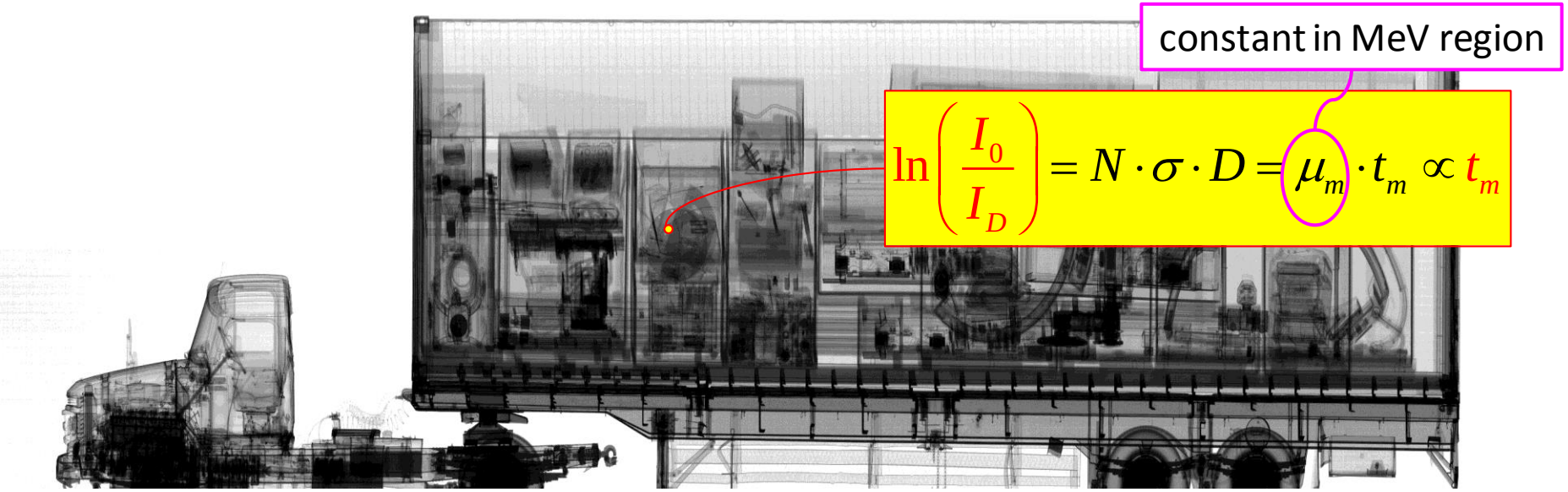
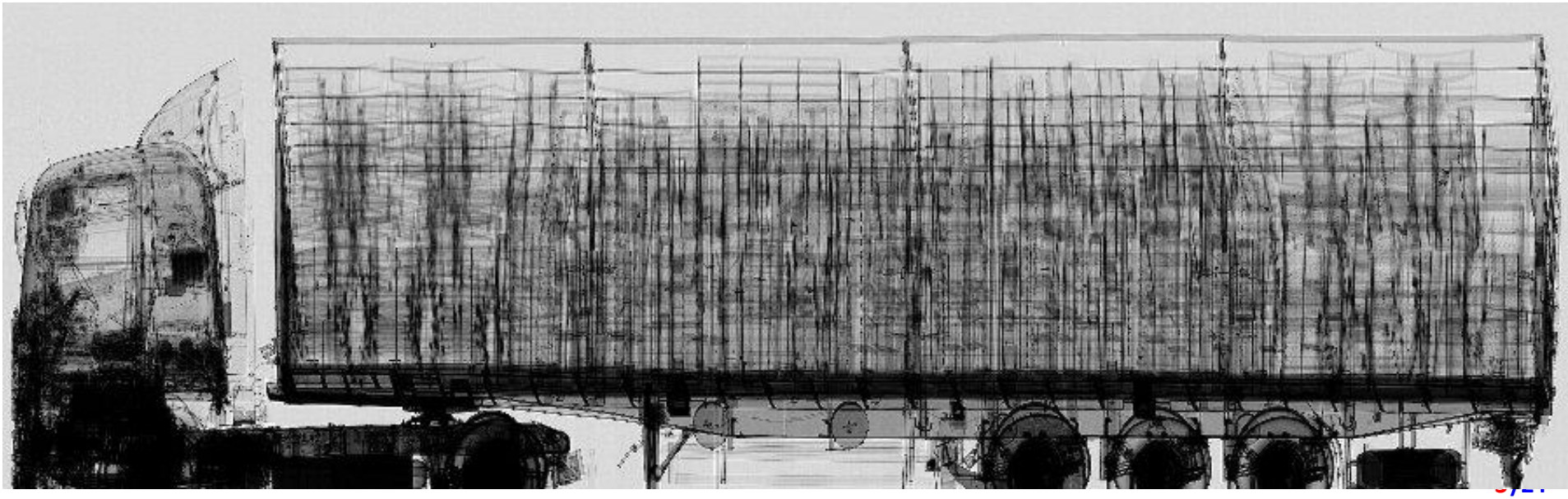
IAEA
International Atomic Energy Agency
Atoms for Peace

Outline

1. **Research motivation**
2. e-LINAC based contrabands detection
3. Summary

MV X-ray images





More information is needed

- In the traditional MV X-ray imaging system, mass-thickness is the only acquired information, which is not enough to indicate the existence of contrabands.
  - Explosives, Drugs, and Special Nuclear Materials
- Fusion of different technologies is needed to locate and identify various contrabands from different aspects.
- Integrating different physics within one system can reduce the system complexity.

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2. **e-LINAC based contrabands detection**

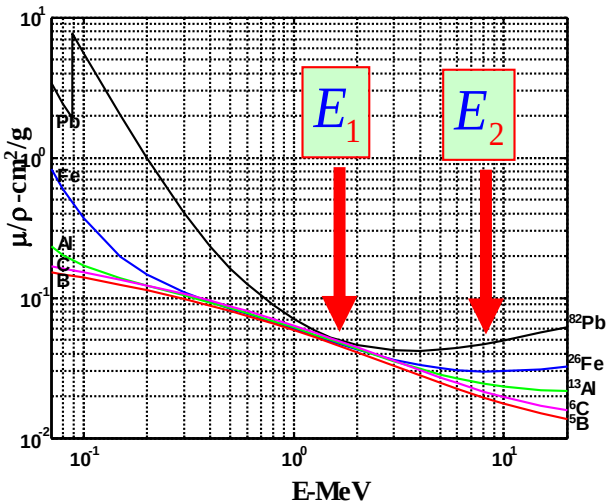
   ① High-Z materials detection with photons

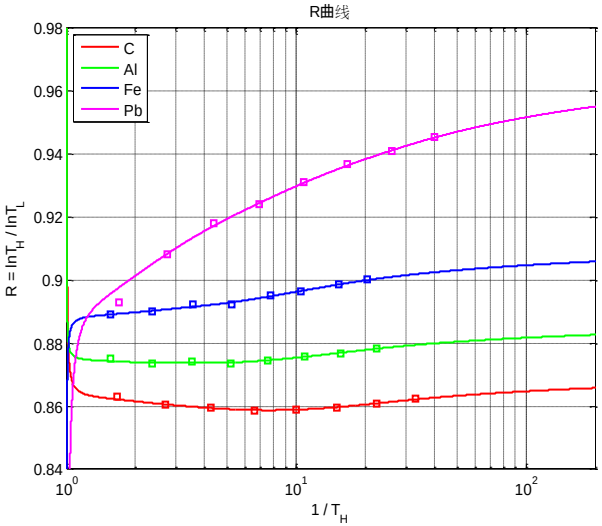
   ② High-Z materials detection with photoneutrons

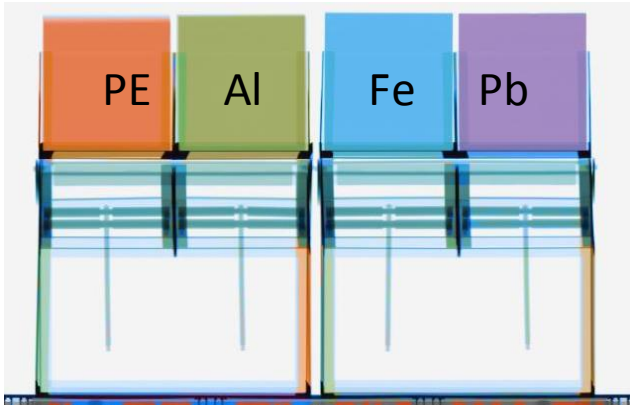
   ③ Explosives or Drugs detection

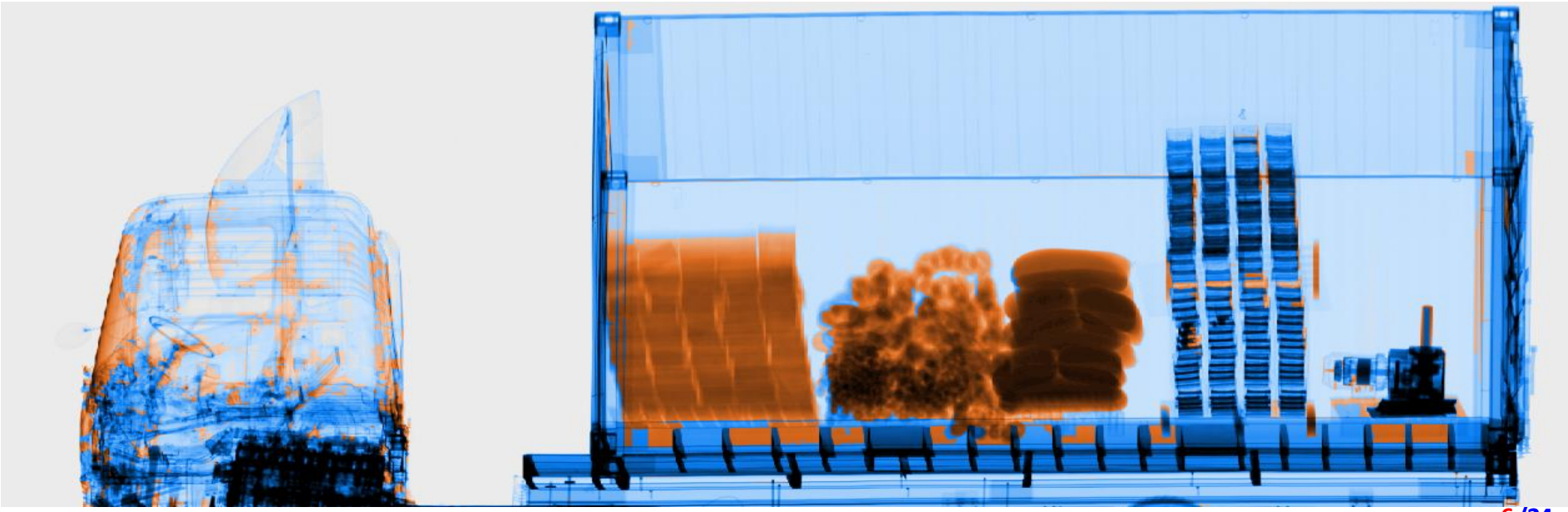
3. Summary

Dual-energy X-ray imaging

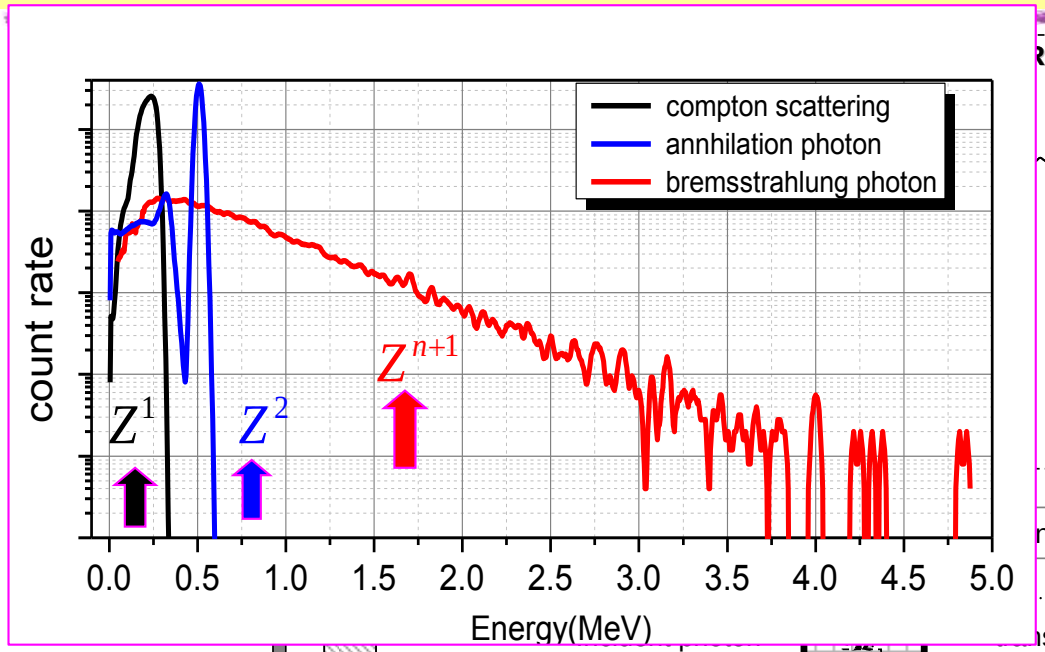


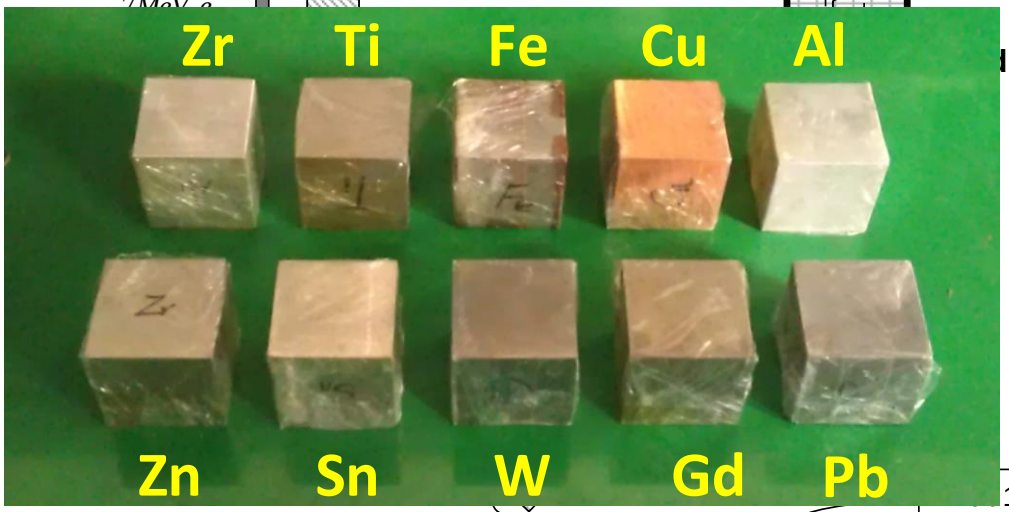


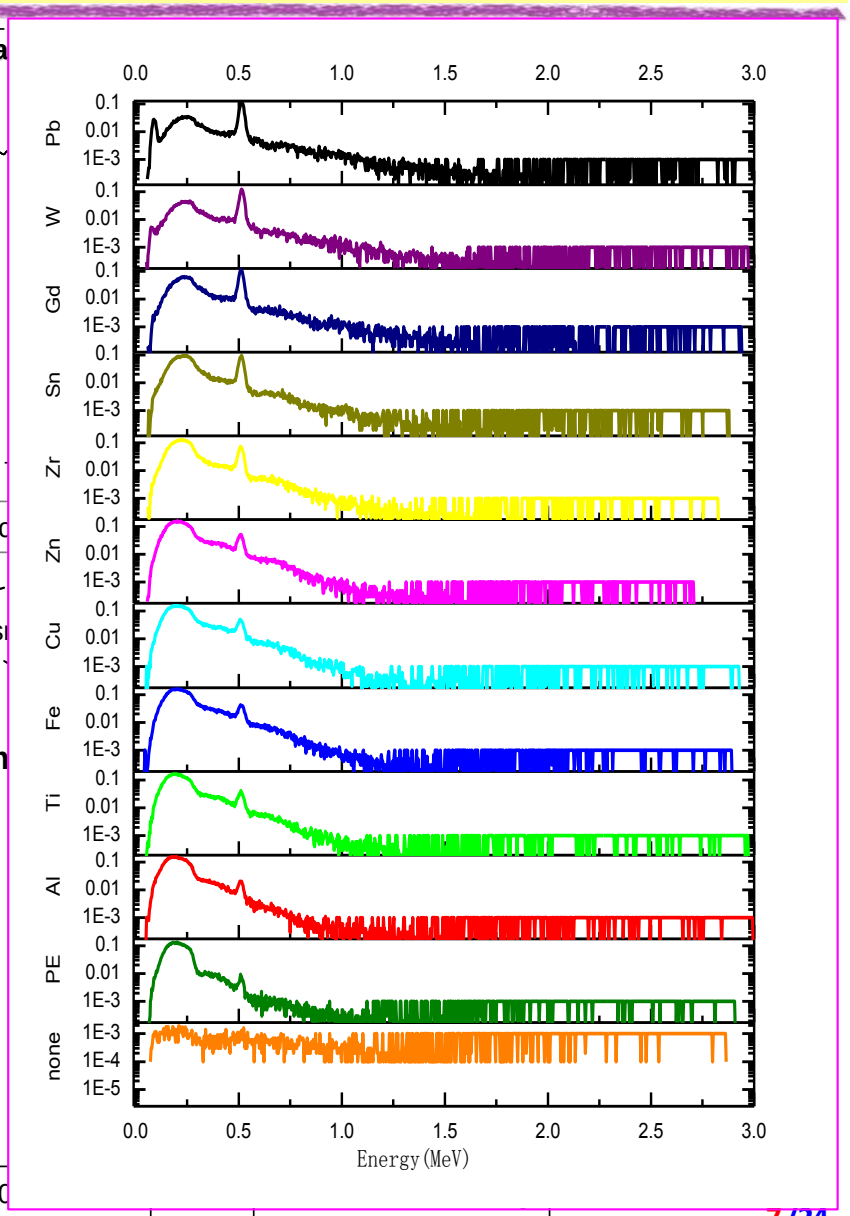




Scattering X-ray analysis

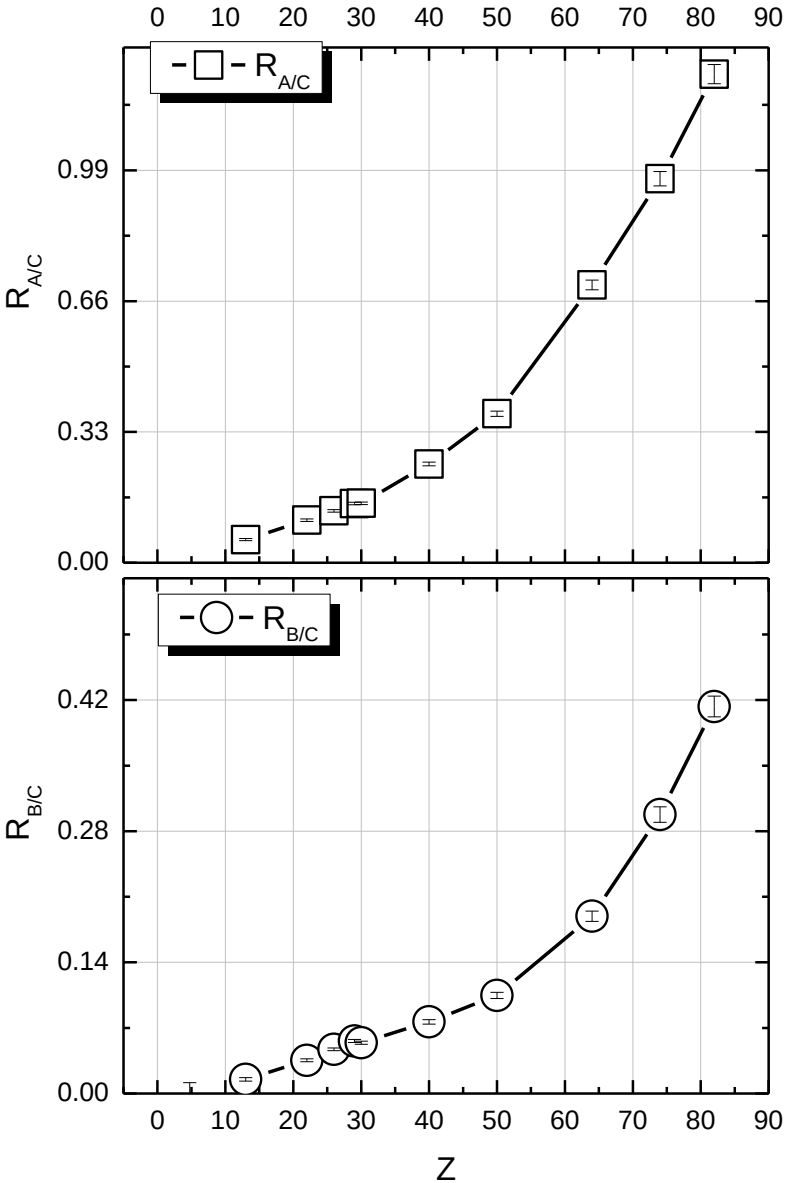


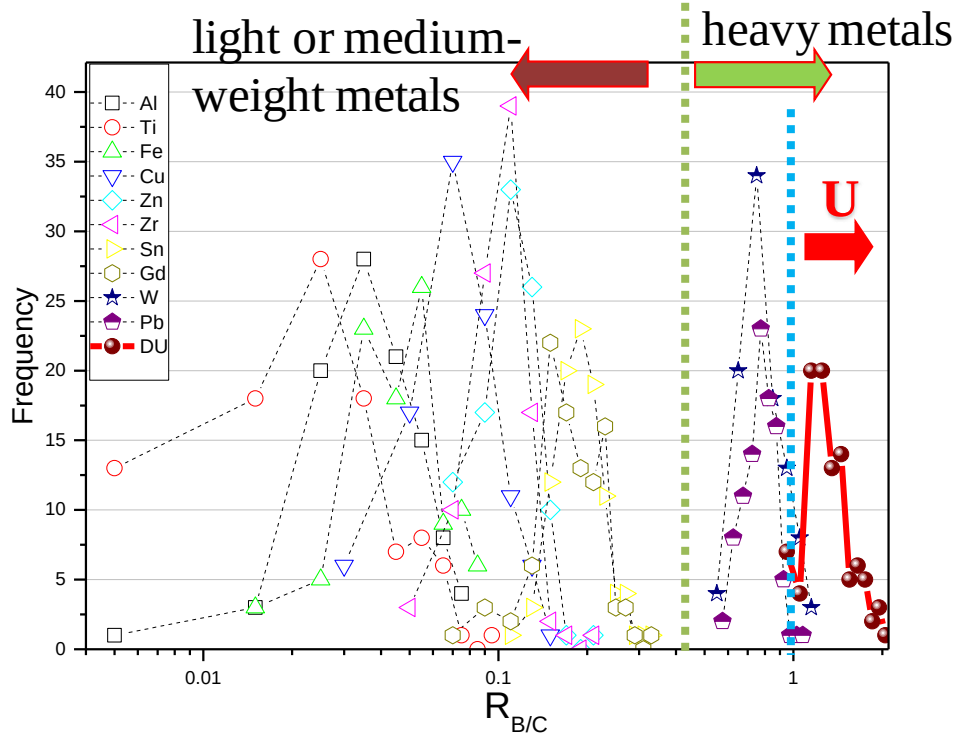




spectra

by analyzing the scattering X-ray spectra, Z information can be acquired





Yigang.Yang, Weiqi Huang, and Yuanjing Li, "*Measurement of Atomic Number by MV X-Ray Scattering Spectra Analysis*," ***IEEE TRANSACTIONS ON NUCLEAR SCIENCE,*** vol. 60, p. 5, 2013.

Outline

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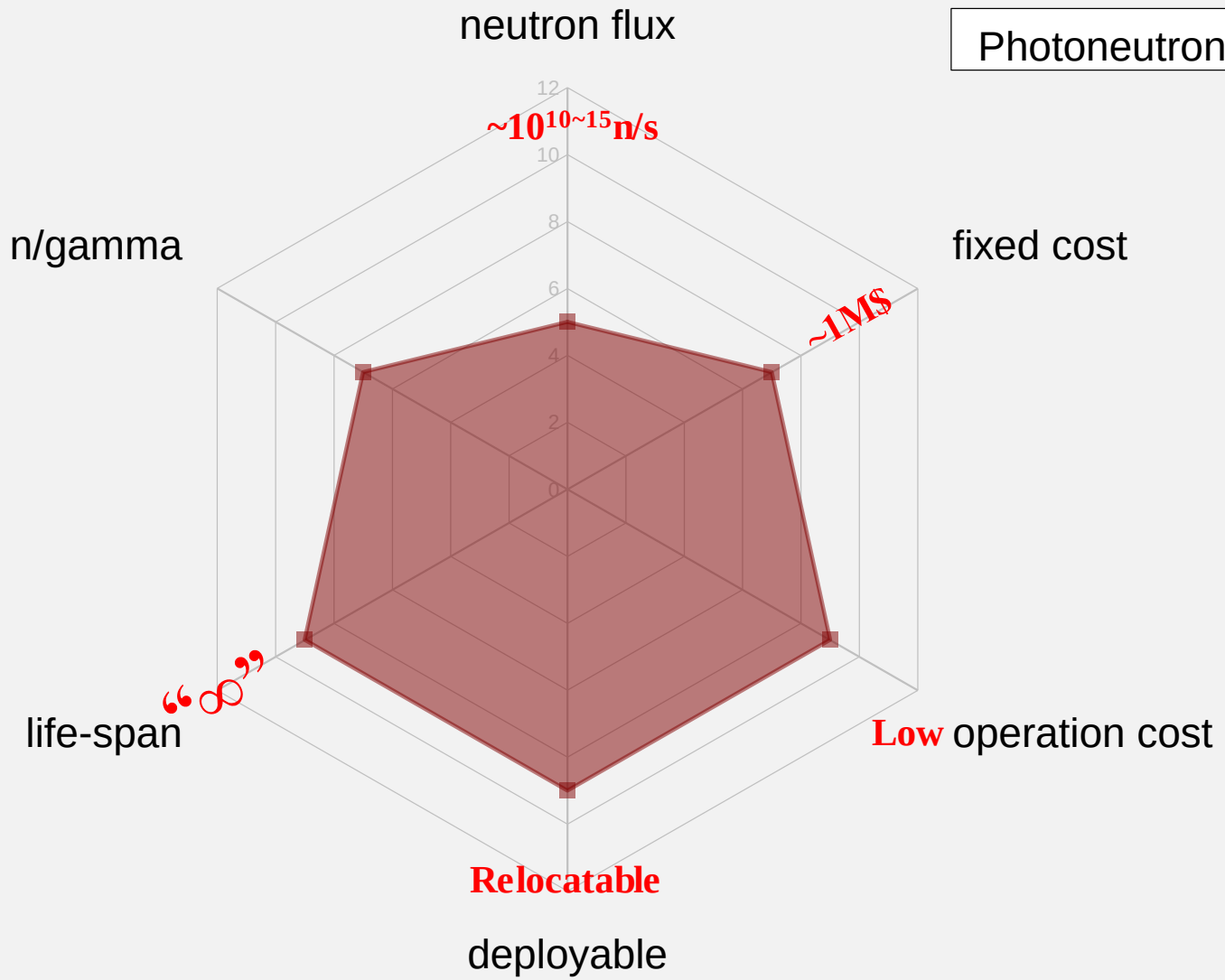
3. Summary

Fermion and neutral particle

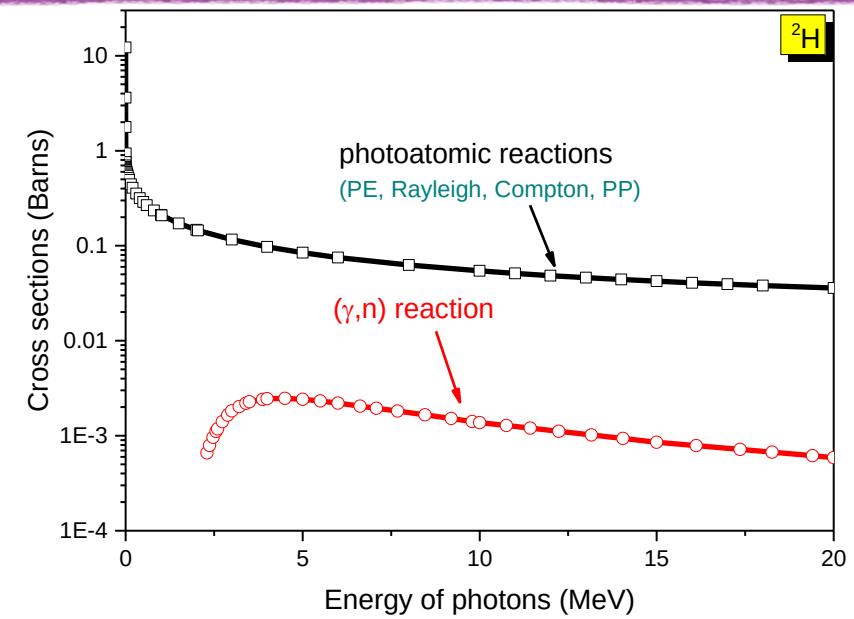
- **Neutron:**
  - Neutral particle: Penetrating capability
  - Fermion: Pauli exclusion principle → Nuclei Structure→ gamma-rays with characteristic energies
- More information about contrabands can be provided by neutron related reactions.

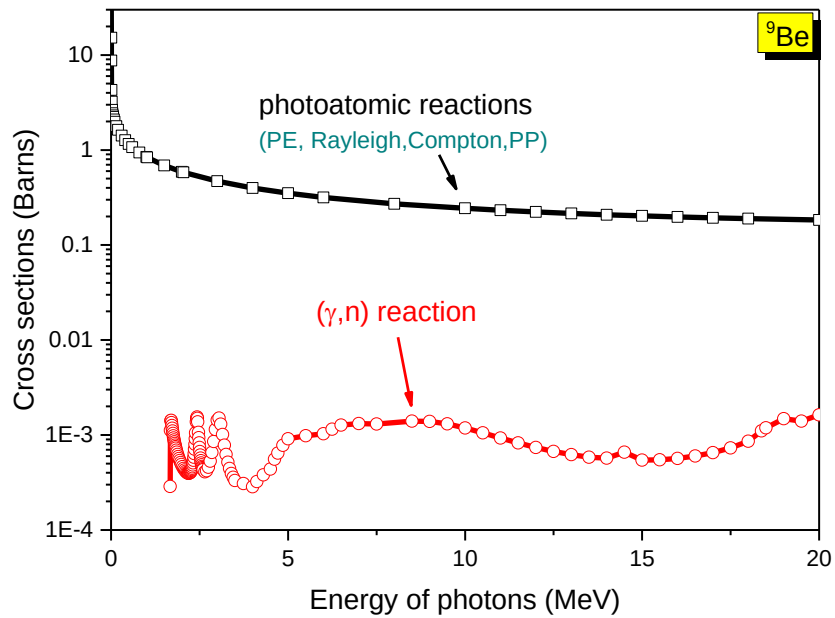
Why e-linac driven neutron source?

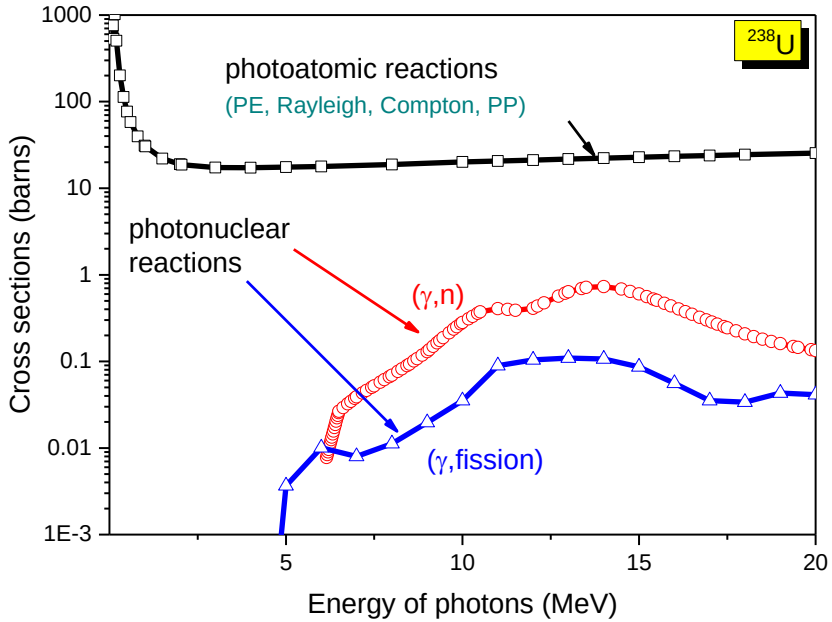
Photoneutron source



photoatomic or photonuclear reactions

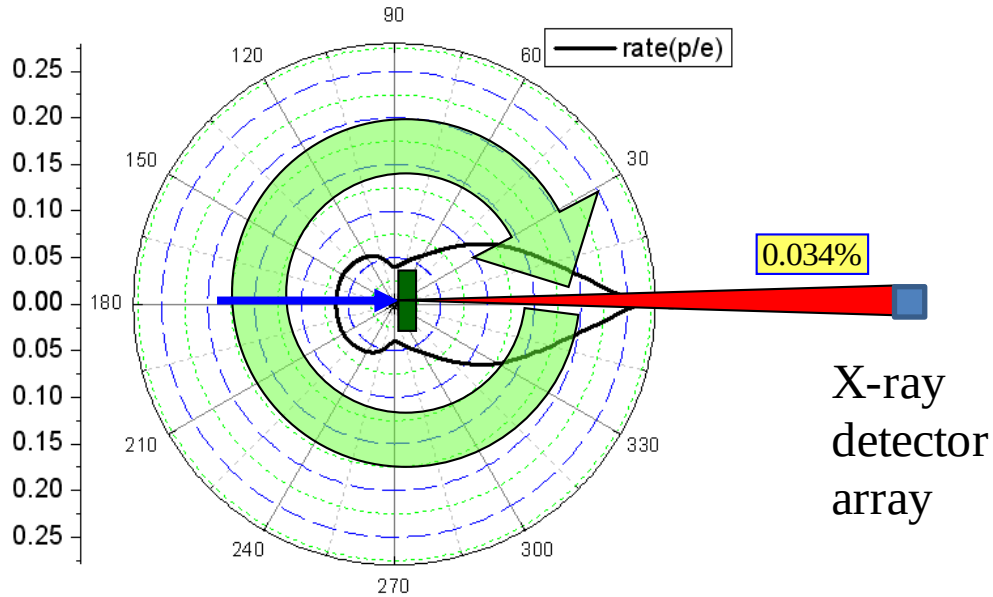


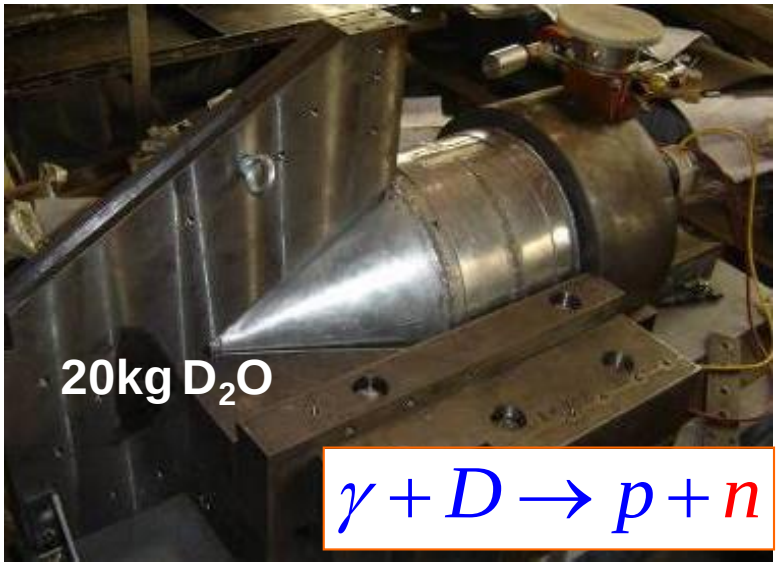


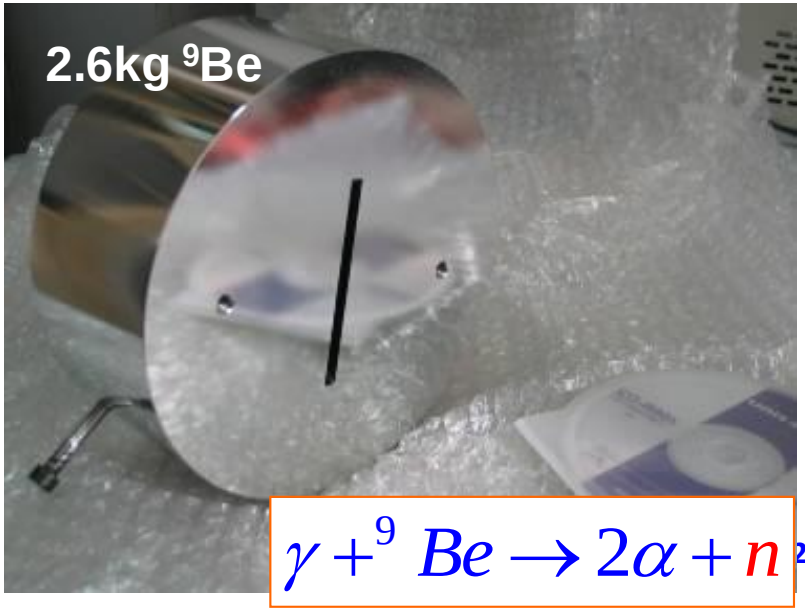


Photons → Neutrons

Angular distribution of X-ray

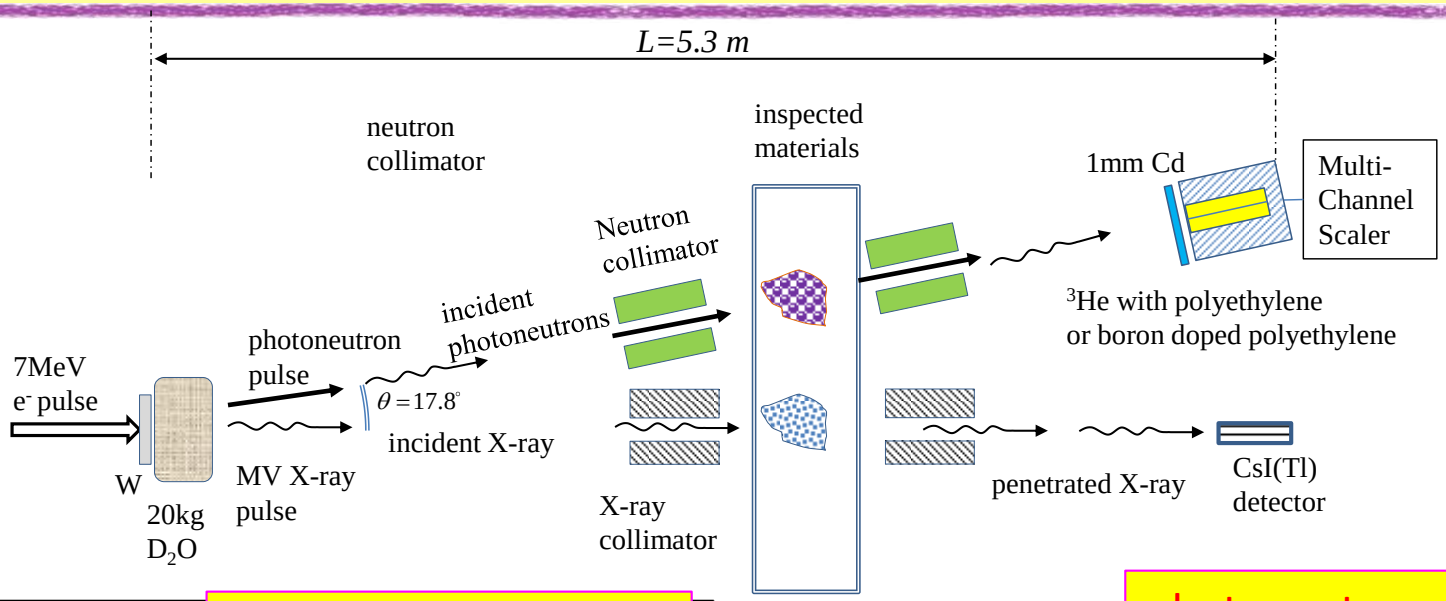


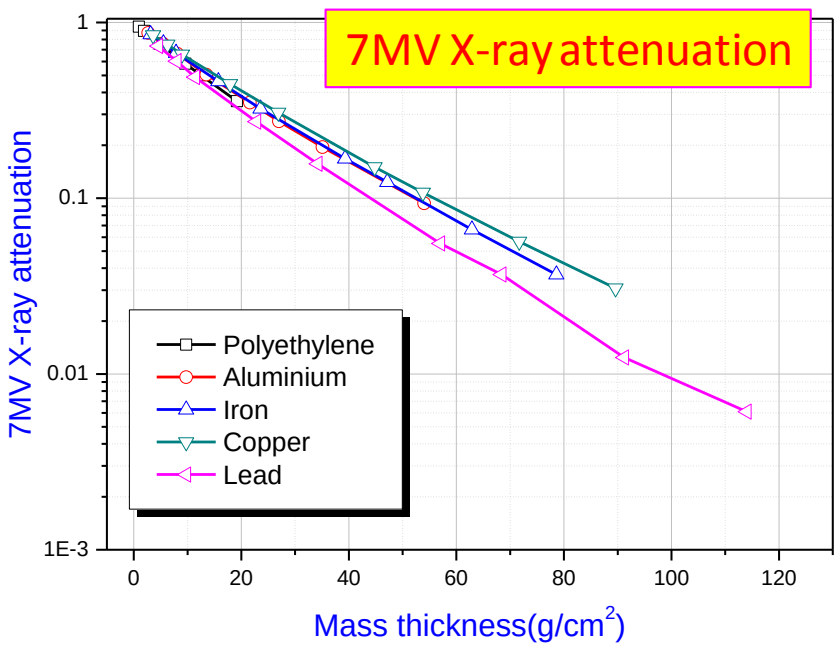


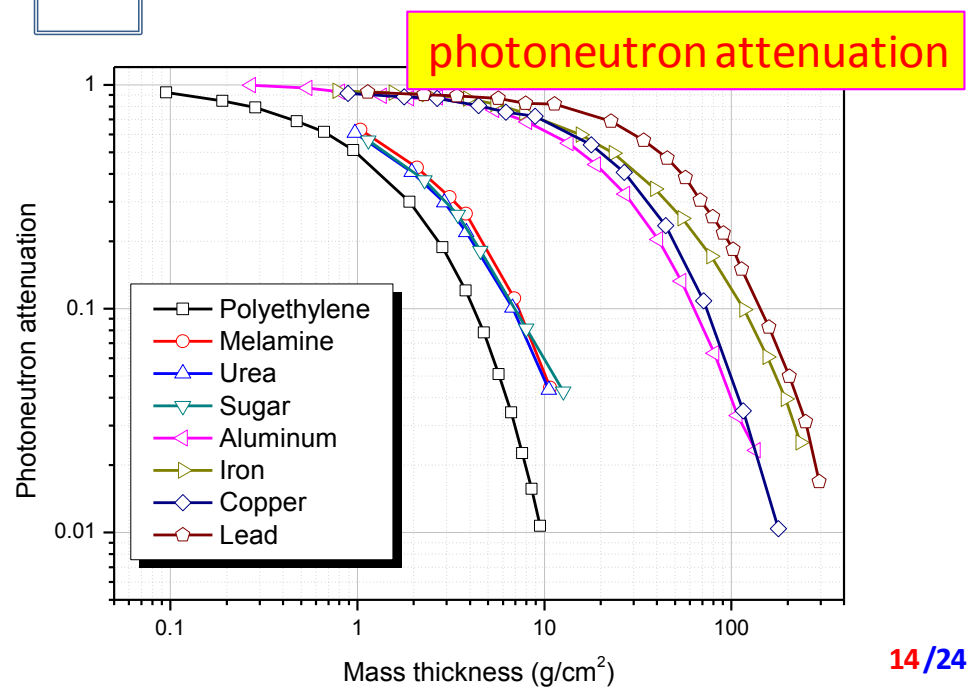


- **photoneutron yield of e-LINAC**
  - 7MeV/100W : **10^{10}n/s**
  - 10MeV/20kW : **6.7×10^{12}n/s**

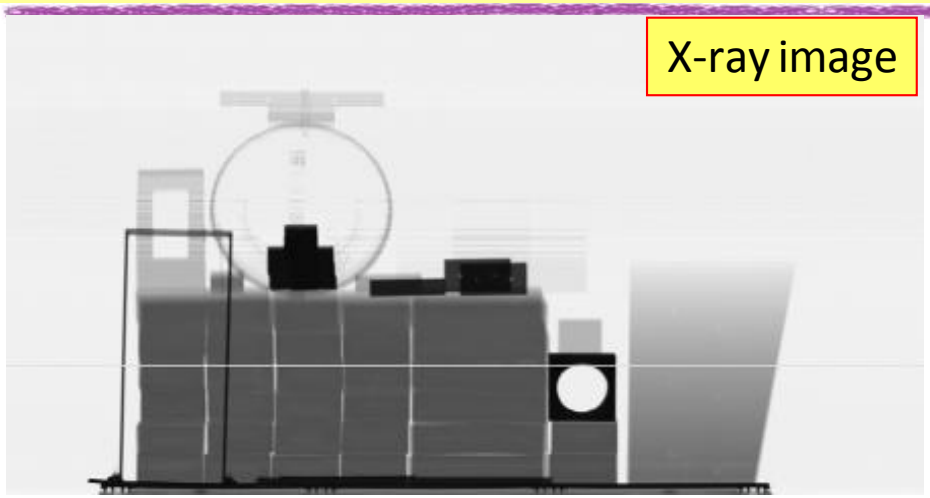
PhotoNeutron X-ray Radiography (PNXR)

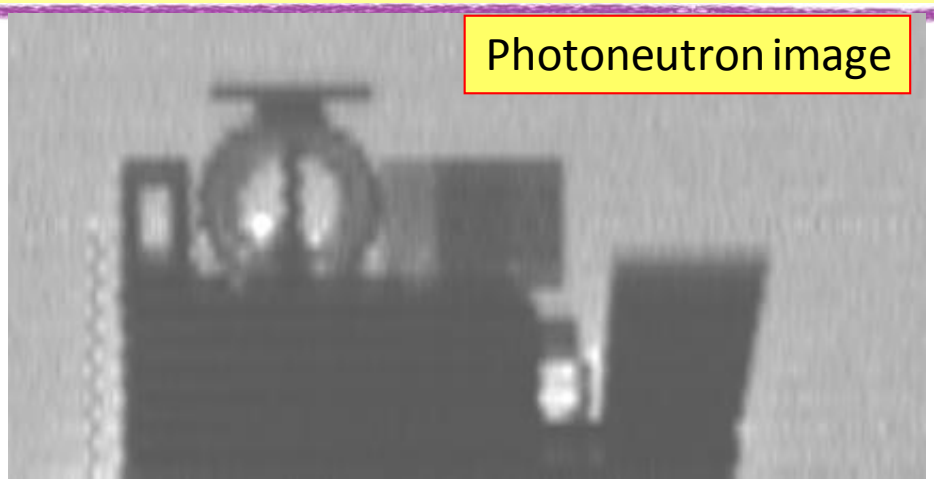




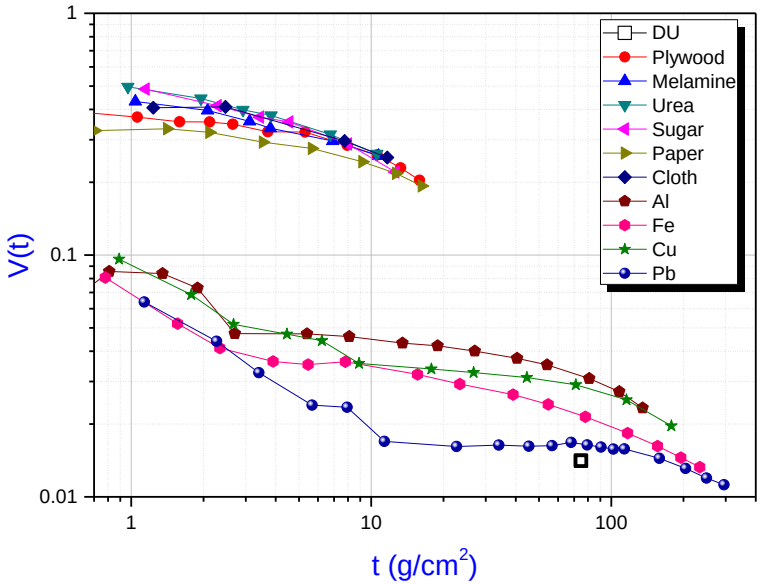


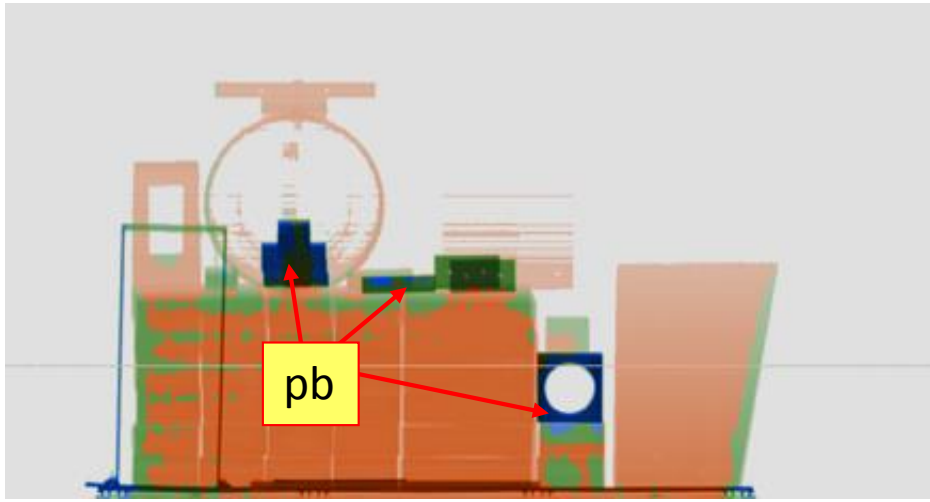
Fused X-ray image and Photoneutron image



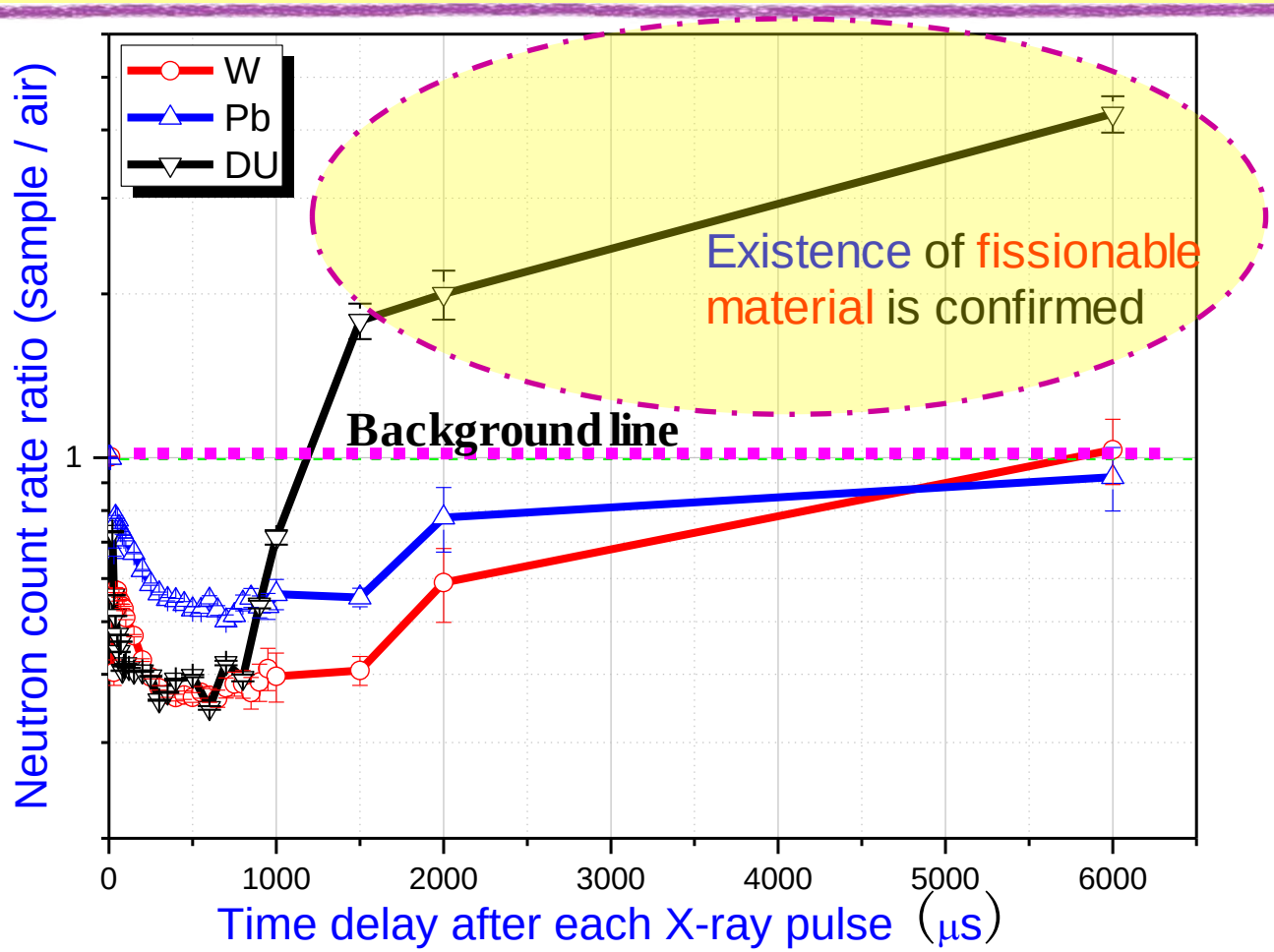


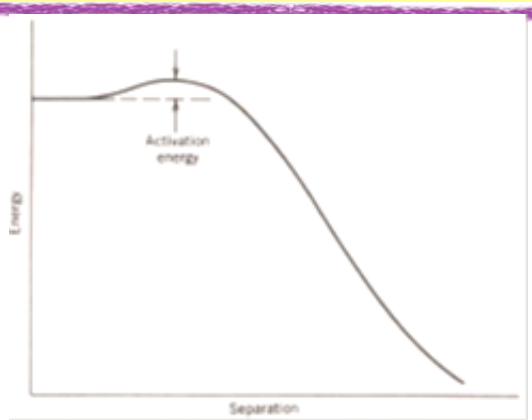
$$V(t) = \frac{\ln\left(\frac{I_n(t)}{I_n(0)}\right)}{\ln\left(\frac{I_X(t)}{I_X(0)}\right)} = \frac{\mu_n(t)\times t}{\mu_X(t)\times t} = \frac{\mu_n(t)}{\mu_X(t)} = \frac{\sigma_n(E_n(t))}{\sigma_X(E_X(t))}$$

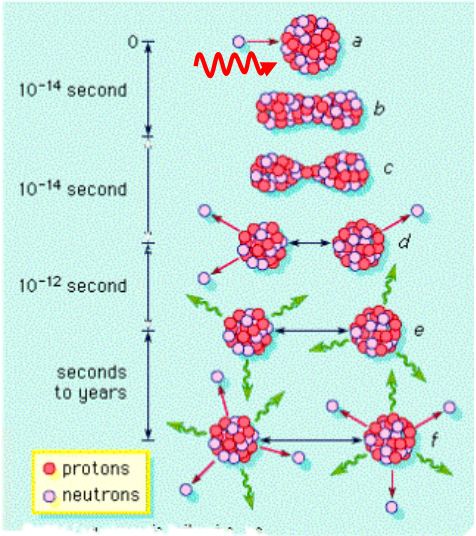




Beta-delayed neutrons detection





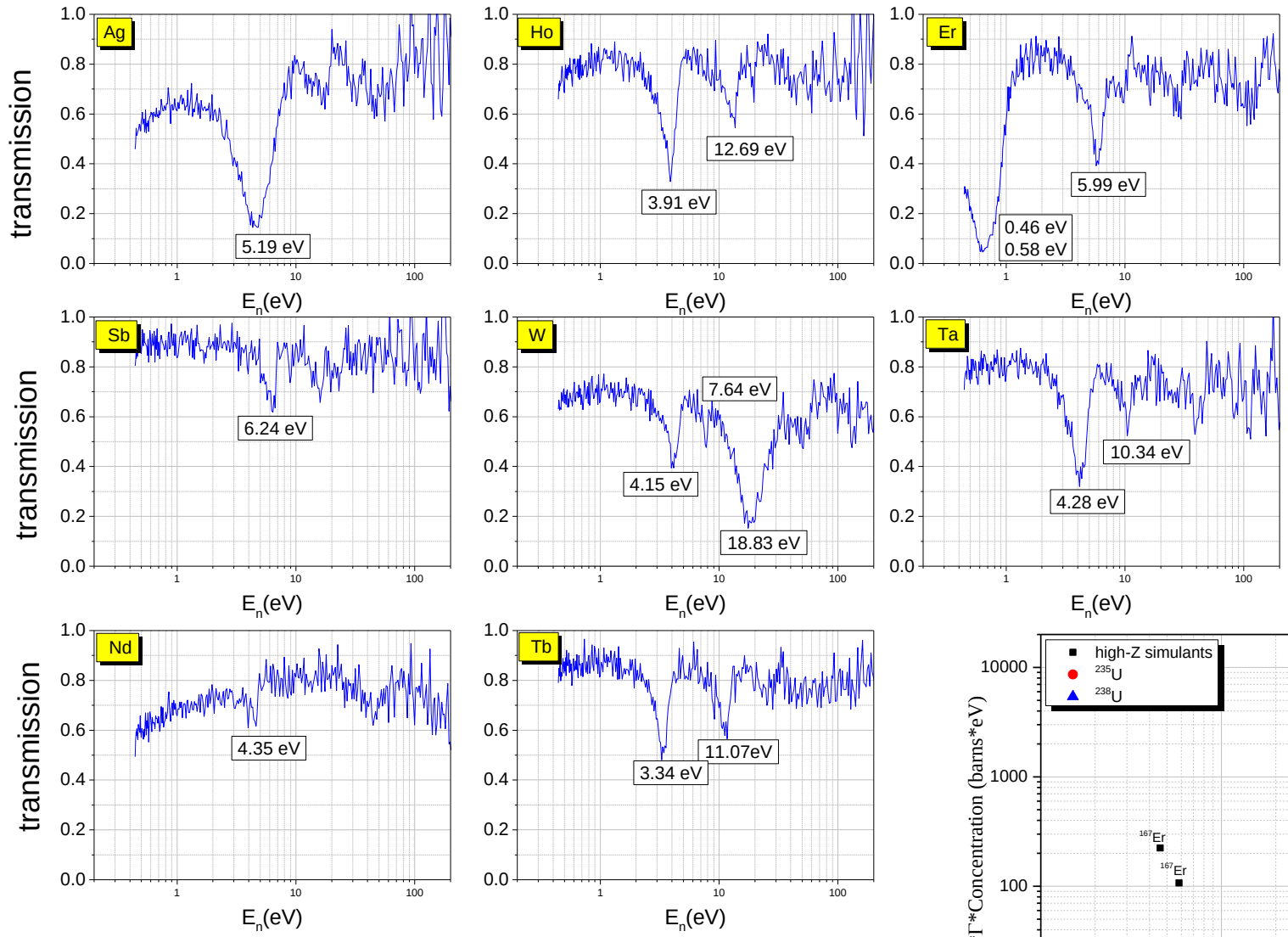


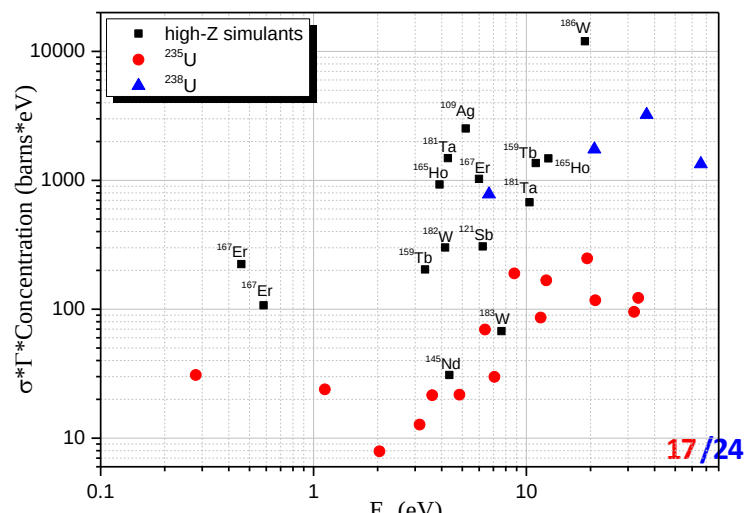
delayed neutrons of U^{235}

Group	1	2	3	4	5	6
$T_{1/2}$ (s)	55.72±1.28	22.72±0.71	6.22±0.23	2.30±0.09	0.610±0.083	0.230±0.025

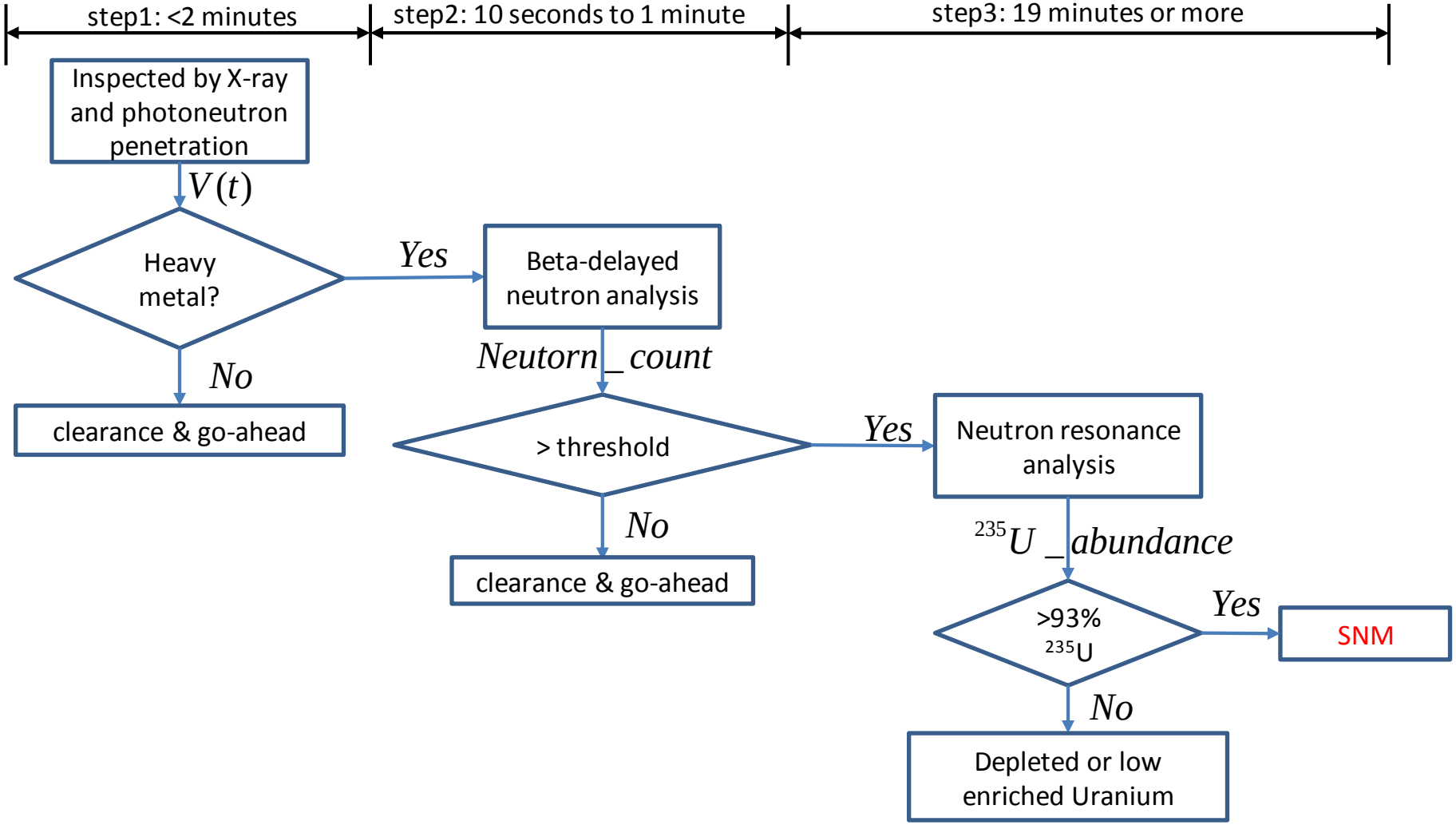
W. H. Yigang Yang, Yuanjing Li, "*The integration of Photon and Neutron method for contrabands detection with a 7MeV Linac*," ***2011 IEEE Nuclear Science Symposium Conference Record***, p. 3, 2011.

Isotopes identification through photoneutron resonant attenuation





Steps for locating and identifying SNMs



Yigang Yang*, Zhi Zhang, Huaibi Chen, Yulan Li, Yuanjing Li. "*Identification of high-Z materials with photoneutrons driven by a low-energy electron linear accelerator*". ***IEEE Transactions on Nuclear Science*** (accepted on Dec. 12, 2016, in press DOI: 10.1109/TNS.2016.2638451)

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   ① High-Z materials detection with photons

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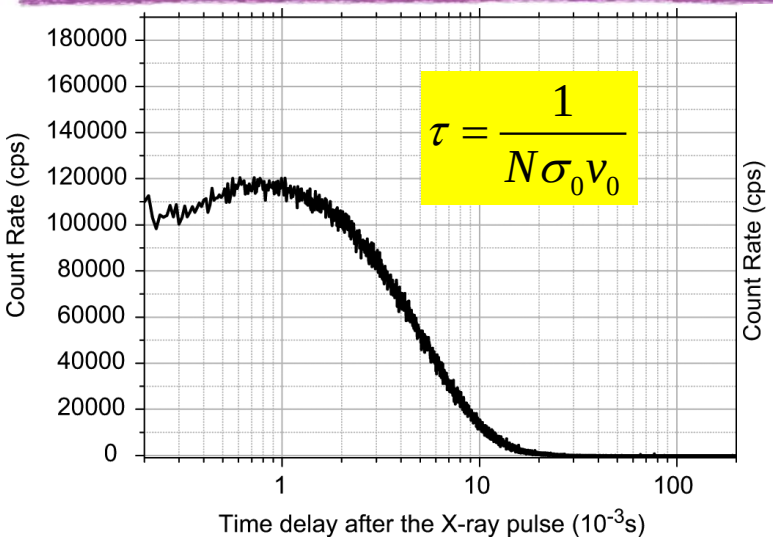
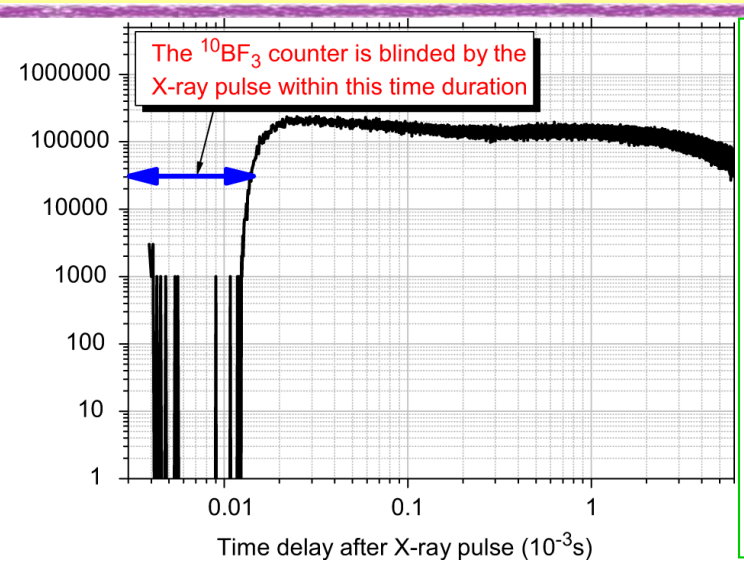
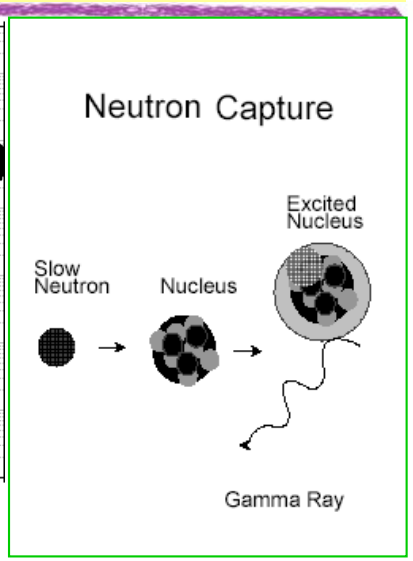
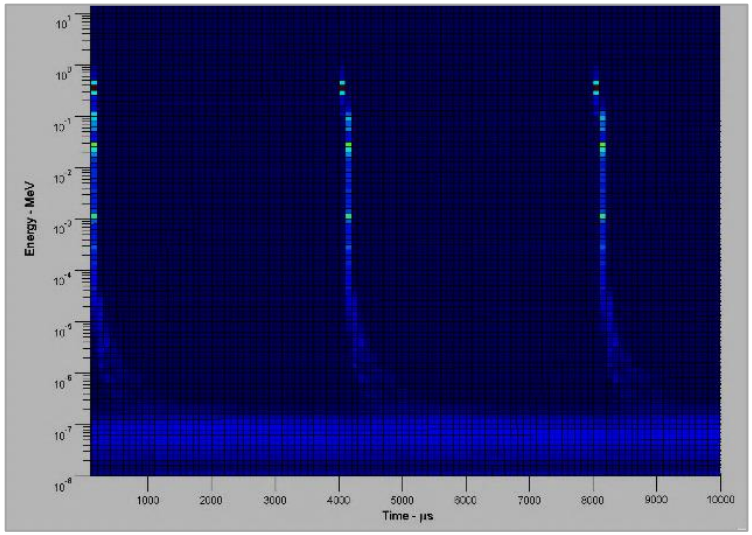
3. Summary

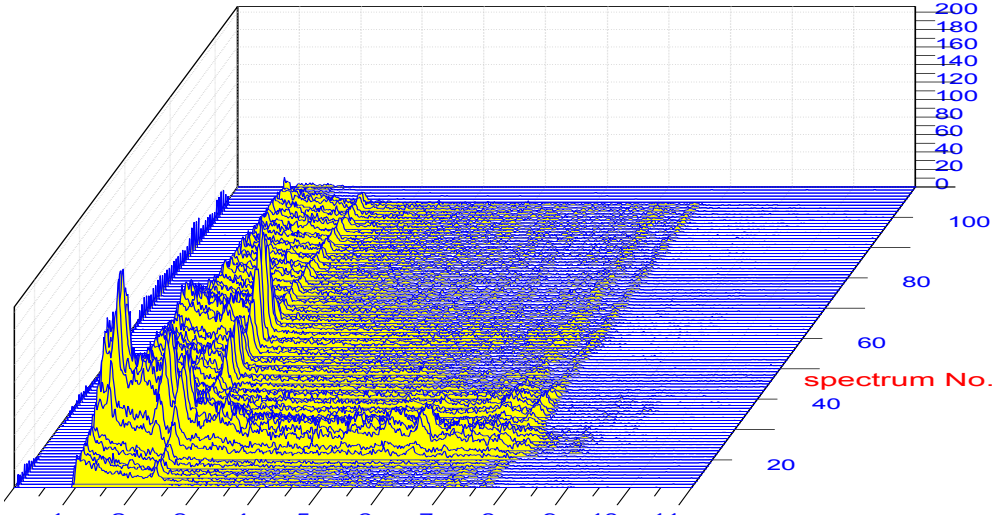
(n, γ) analysis for explosives or drugs





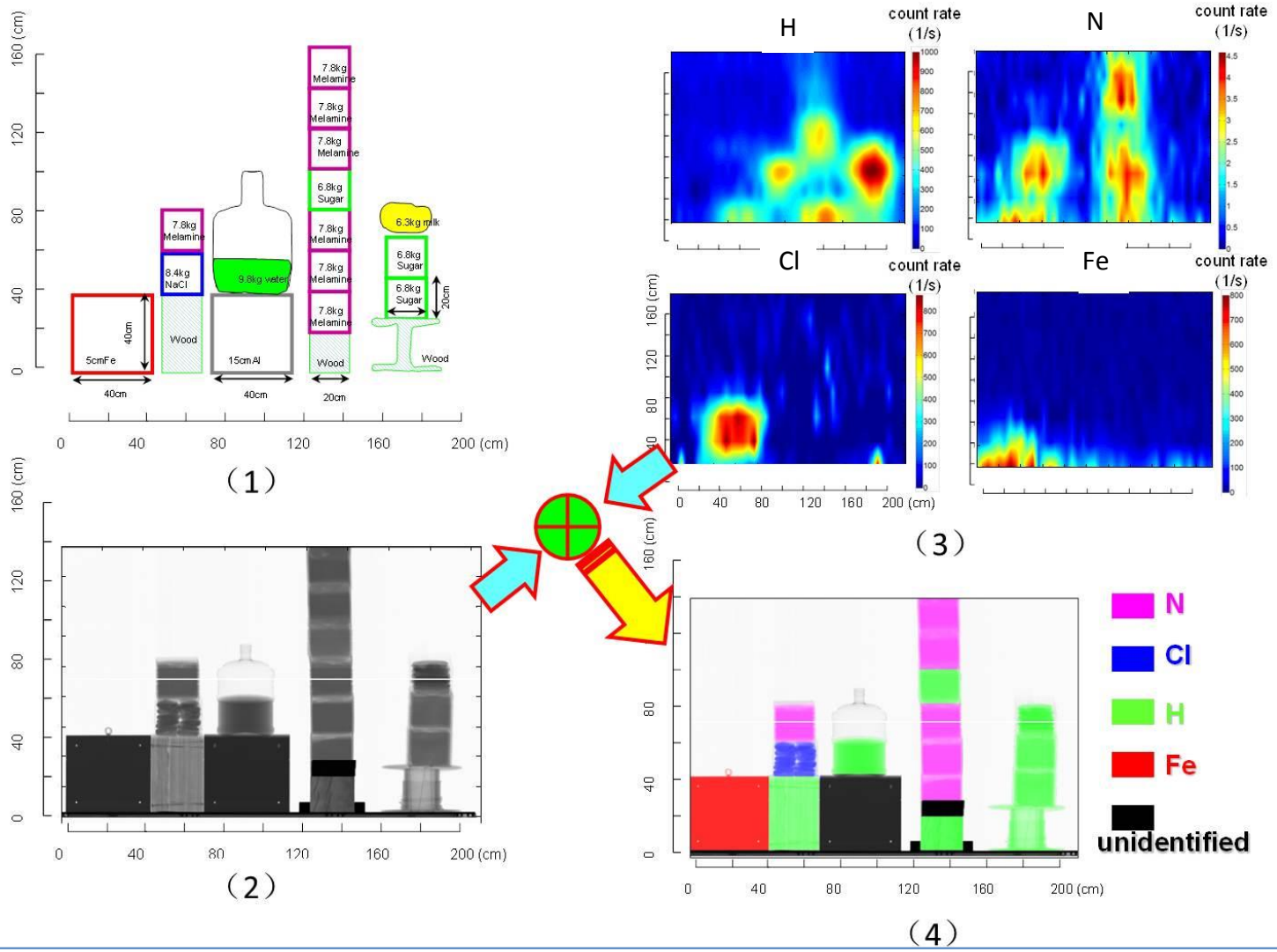






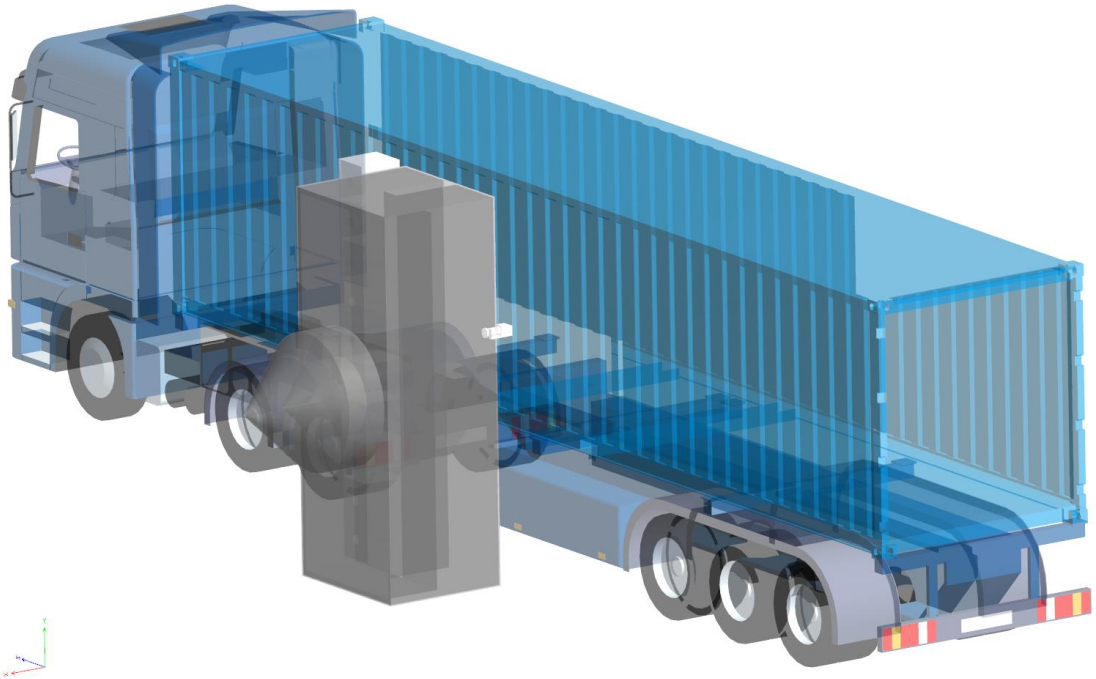
Y. Yigang, L. Yuanjing, W. Haidong, L. Tiezhu, and W. Bin, "*Explosives detection using photoneutrons produced by X-rays*," ***Nuclear Inst. and Methods in Physics Research, A,*** vol. 579 (2007), pp. 400-403

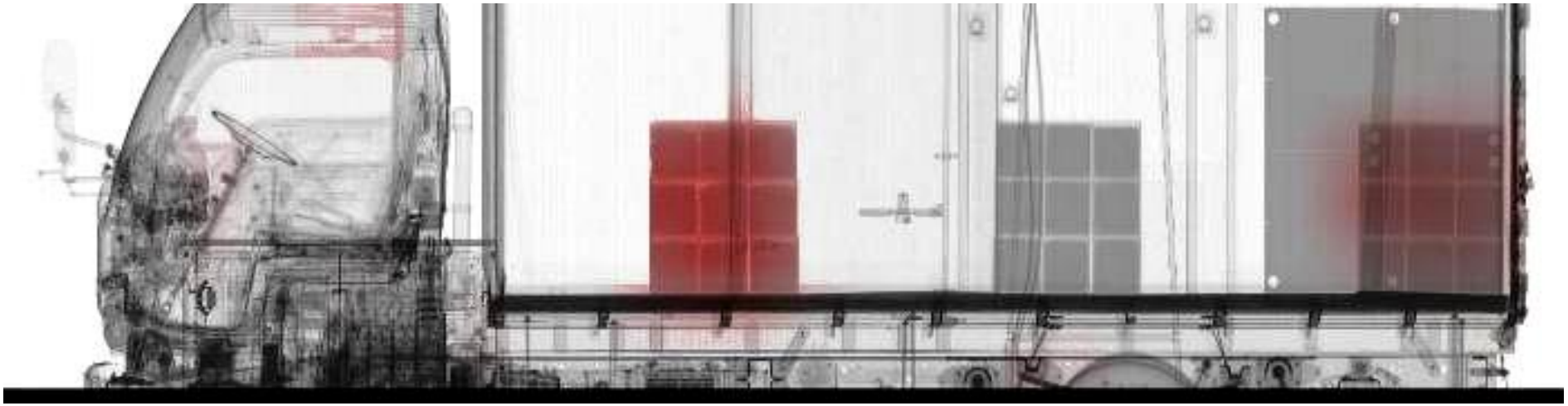
Fusion of X-ray image and elemental concentration distribution



Yigang Yang, Jianbo Yang and Yuanjing Li, "*Fusion of X-ray Imaging and Photoneutron Induced Gamma Analysis for Contrabands Detection*," ***IEEE TRANSACTIONS ON NUCLEAR SCIENCE***, vol. 60, p. 6, 2013.

Drugs or explosives detection system





3.Summary

- An e-LINAC can produce both X-rays and photoneutrons.
- Properties of the photoneutron source:

  ① **High neutron yield**

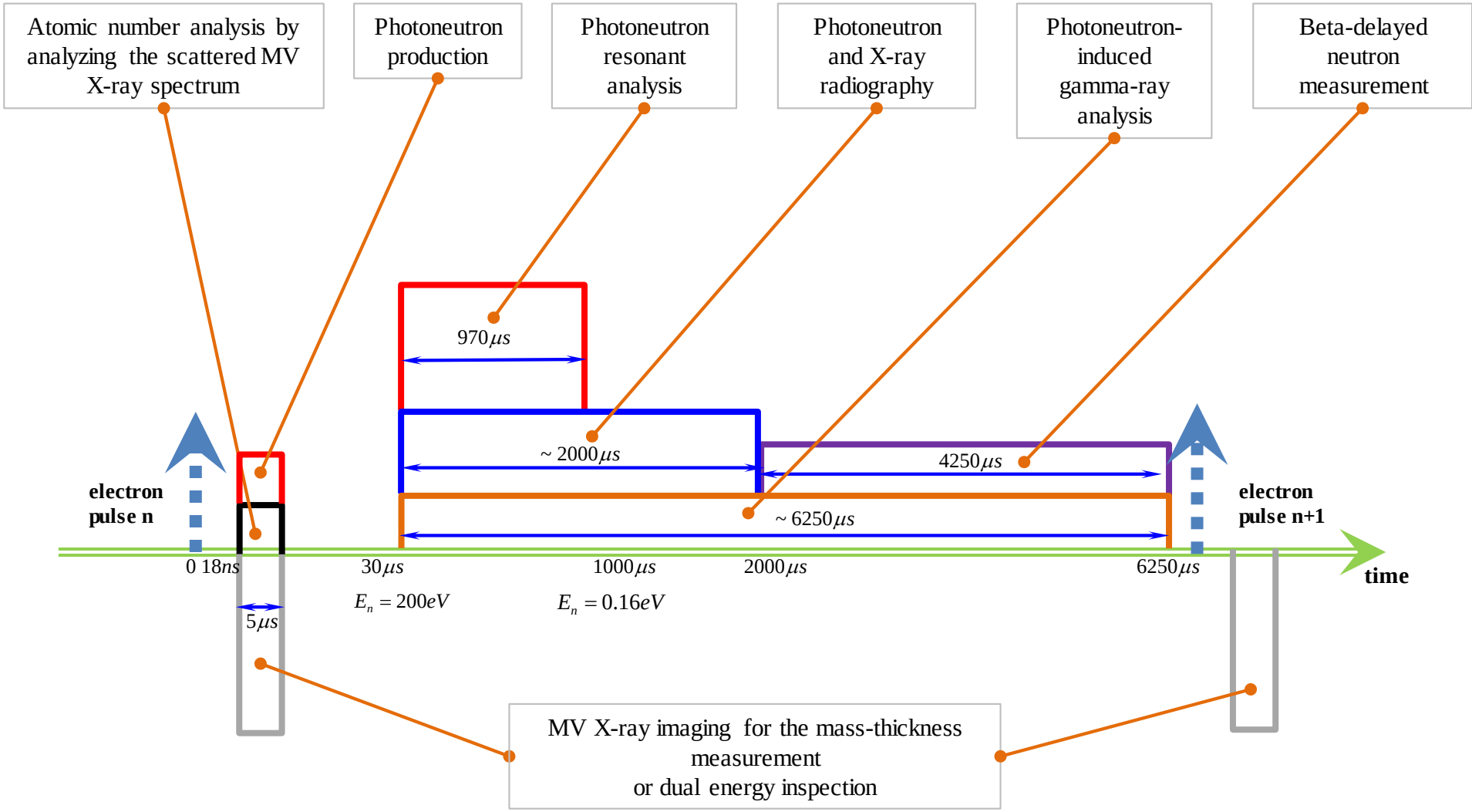
  ② **Long life-span & Robustness**

  ③ **Relocatable** and suitable for the **field use**

  ④ **Pulsed mode**, enabling the energy selective methods

- The philosophy of "**one-source, two-radiation, multi-physics**" can be supported by the e-LINAC driven photoneutron source to enhance the contrabands detection capability.

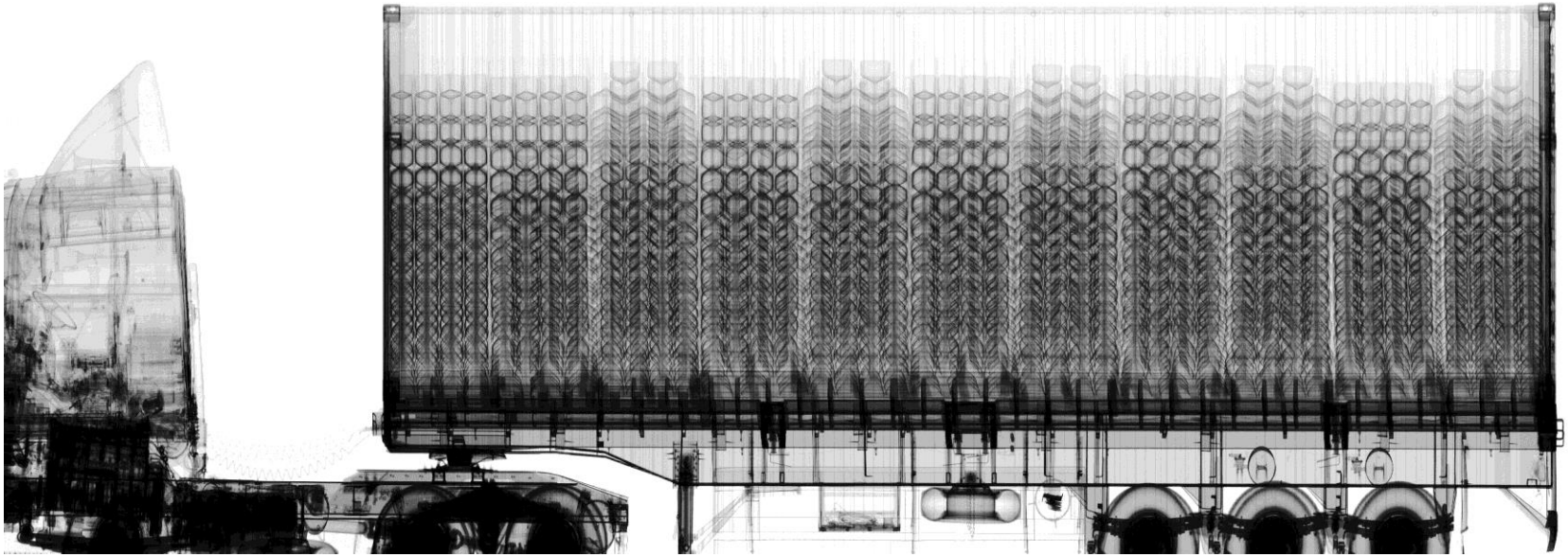
"one-source, two-radiation, multi-physics" for the contrabands detection



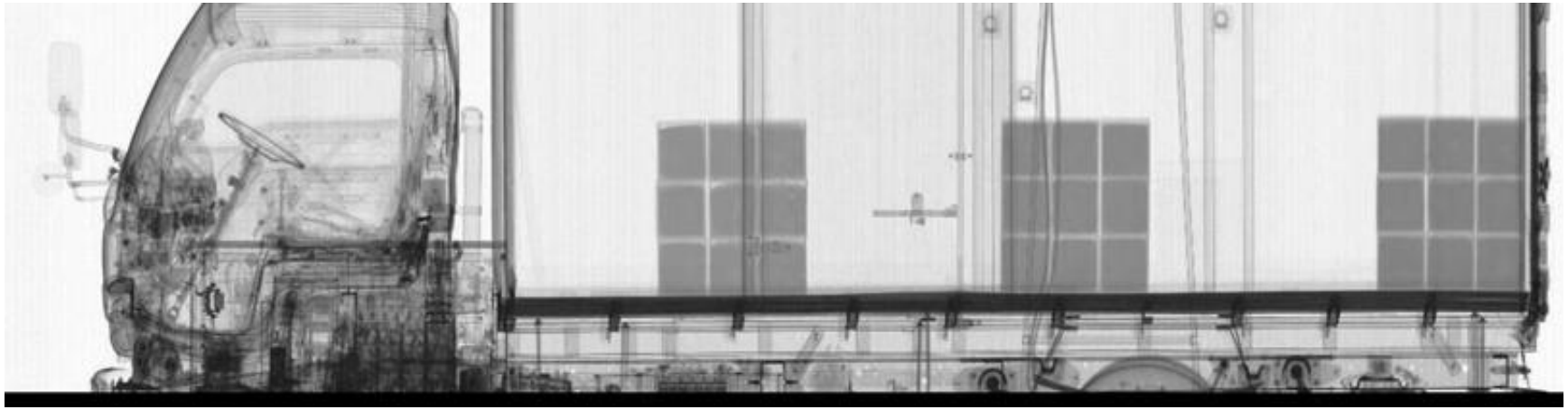
Thanks for your attention

&

Questions please



1. Research motivation



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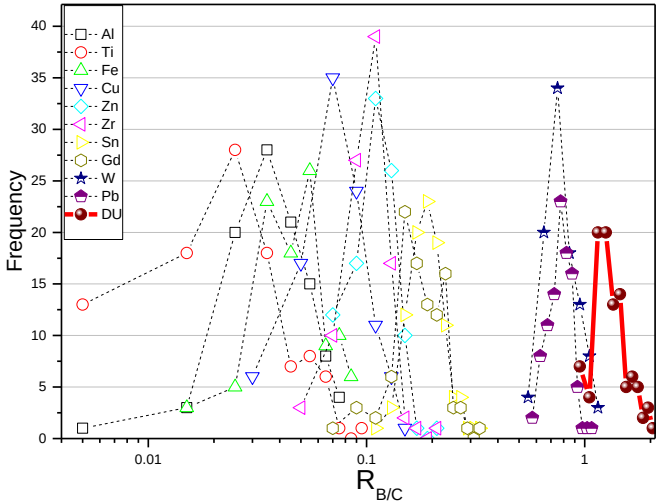
Al
Ti
Fe
Cu
Zn
Zr
Sn
Gd
W
Pb
DU
Frequency
0
5
10
15
20
25
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35
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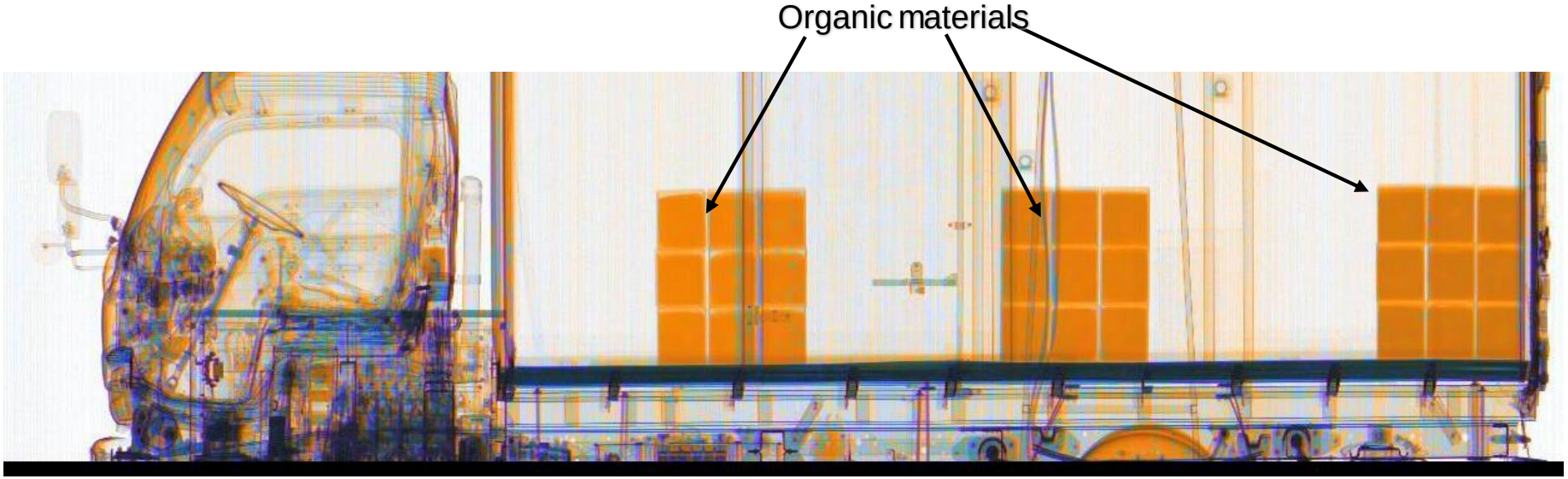
0.01
0.1
1
$R_{B/C}$


Organic materials