No. of Poster: IAEA-CN-218/96

Center for Strategic Studies

The Feasibility Analysis of the Materials of the Nuclear Explosion with the Fission Product Xenon

SU Jia-hang

（Center for Strategic Studies， China Academy of Engineering Physics, China）

IAEA
International Atomic Energy Agency

Introduction

The identification of the fissile material of a nuclear explosion is quite an important part of the post-explosion nuclear forensics investigation, and it is also very important in nuclear non-proliferation field. The fissile materials used in nuclear weapons are usually Highly Enriched Uranium(HEU) and Plutonium(Pu). It is possible to distinguish U-235 and Pu-239 by analyzing the isotopic components of the fissile fragments due to the slight difference of the fissile products between U-235 and Pu-239 in the same neutron energy. One series of these characteristic isotopes are the Xenon isotopes, including Xe-131m, Xe-133m, Xe-133, and Xe-135, which are easy-spreading, stable and easy-detectable. By analyzing the ratio of Xenon isotopes, U-235 and Pu-239 may be distinguished. In this poster, with the demonstration of the difference of the ratio of Xenon isotopes between U-235 and Pu-239, the feasibility to identify the fissile material of a nuclear explosion is analyzed. Besides, by numerically simulating other fissile fragments, the fissile materials may be further confirmed.

The theoretical analysis of the radioactivity change of the Xenon isotopes

For the fissile fragment, its activity composes of the fissile contribution, and the decay contribution both from the mother nuclides and the daughter nuclides. Taking Xe-135 for example, and ignoring the short-half-life intermediate products, we can get the nucleon densities of I-135 and Xe-135 as shown below.

$$\frac{dN_I(t)}{dt} = \gamma_I \Sigma_f \phi \delta(t-t_0) - \lambda_I N_I(t)$$

$$\frac{dN_{Xe}(t)}{dt} = \gamma_{Xe} \Sigma_f \phi \delta(t-t_0) + \lambda_I N_I(t) - (\lambda_{Xe} + \sigma_a^{Xe} \phi \delta(t-t_0)) N_{Xe}(t)$$

For the nuclear explosion, the original nucleon densities of I-135 and Xe-135 are both 0. So we solve the equations above with the assumption that the nuclear explosion begins at t=0 and the neutron flux density reaches the maximum and then fall back to 0 immediately. Thus the nucleon densities of I-135 and Xe-135 can be shown as

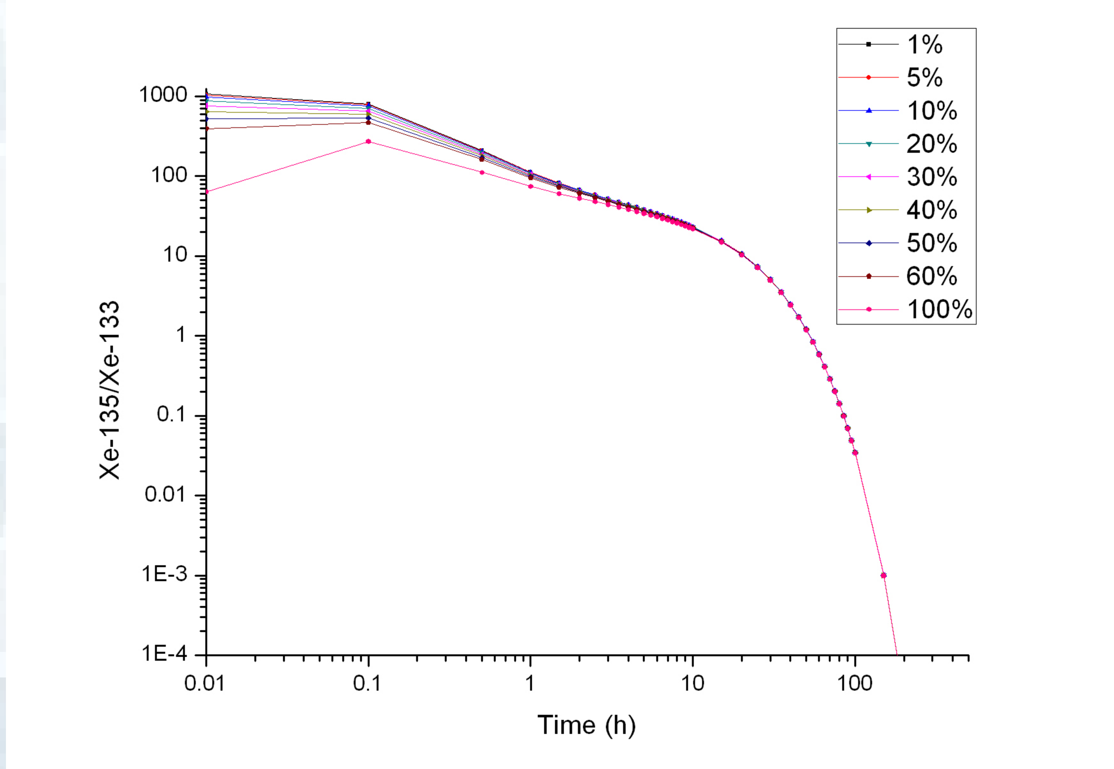
$$N_I(t) = \begin{cases} \gamma_I \Sigma_f \phi & t=0 \\ \gamma_I \Sigma_f \phi e^{-\lambda_I t} & t>0 \end{cases}$$

$$N_{Xe}(t) = \begin{cases} \gamma_{Xe} \Sigma_f \phi & t=0 \\ \dfrac{\lambda_I}{\lambda_{Xe} - \lambda_I} \gamma_I \Sigma_f \phi (e^{-\lambda_I t} - e^{-\lambda_{Xe} t}) + \gamma_{Xe} \Sigma_f \phi e^{-\lambda_{Xe} t} & t>0 \end{cases}$$

For U-235 and Pu-239, the cumulative yield of Xe-135 is almost the same, so it is extremely difficult to distinguish U-235 and Pu-239 from each other after the peak point. Thus the time zone which can be used to derive the fissile material is limited, and the sampling work should be done as soon and near as possible to get an accurate estimation.

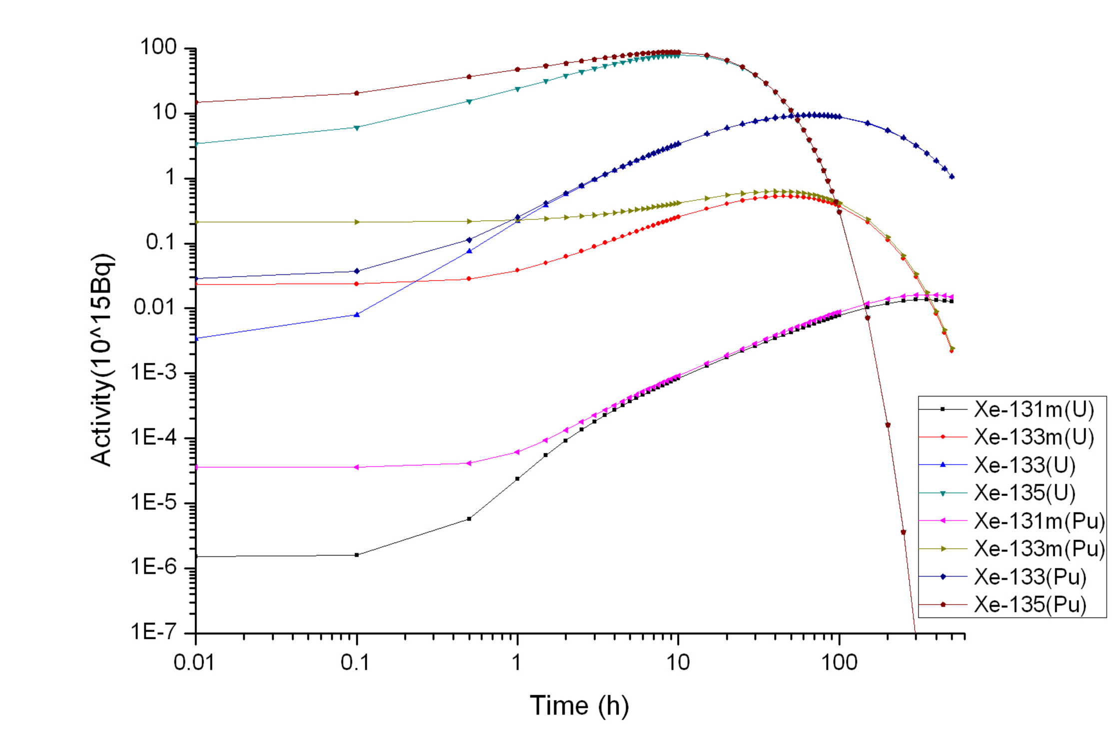
The influence of the nuclear loading efficiency to the simulation

In a nuclear explosion, the bomb requires higher neutron flux to get higher nuclear loading efficiency. And for fissile product like Xe-135, which has a relatively high neutron-absorption cross-section, the higher the neutron flux is, the higher the probability of neutron-absorption reaction is. So it will affect the ratio of Xenon isotopes, for example, Xe-135/Xe-133. But by the result of the numerical simulation, as is shown below, we know that in the low nuclear loading efficiency area, the ratio Xe-135/Xe-133 doesn't change much with the nuclear loading efficiency. What's more, after a few hours, the ratio Xe-135/Xe-133 nearly doesn't change with nuclear loading efficiency, and goes consistently. In the real situation, the loading efficiency of a nuclear explosion usually stays low, so the influence of the nuclear loading efficiency can be ignored in the numerical simulation.

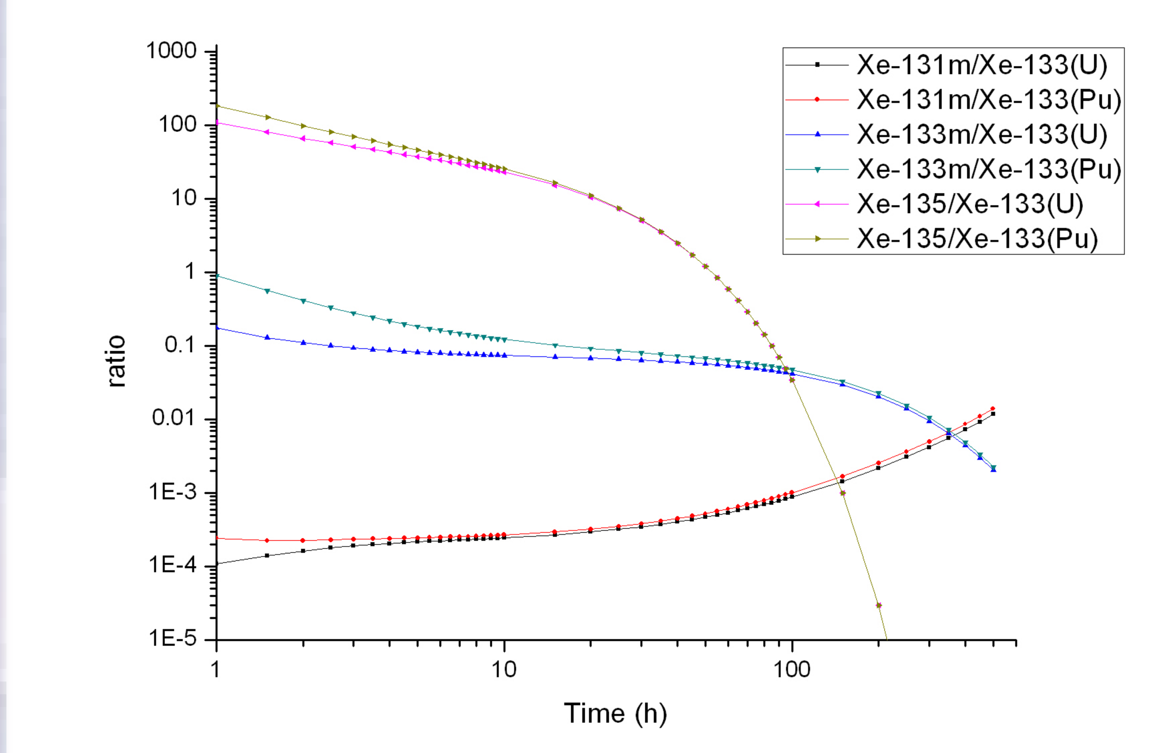


The simulation for the radioactivity change of the Xenon isotopes

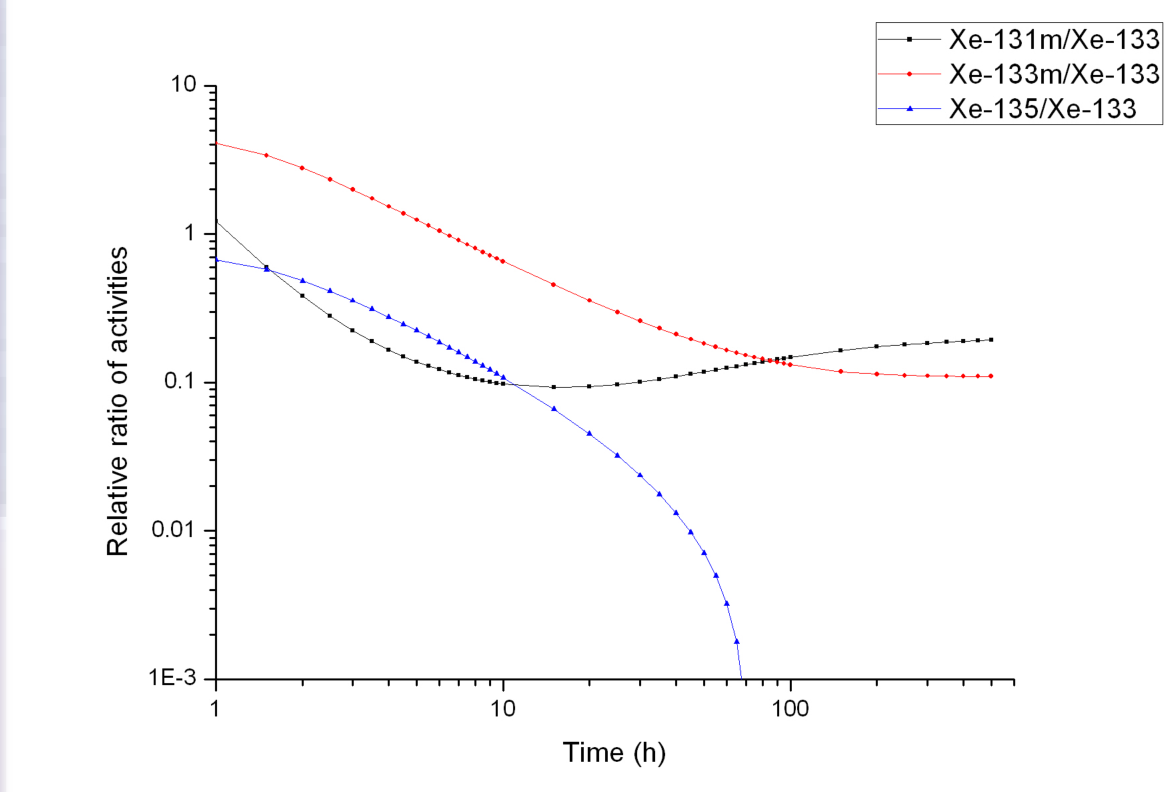
With all that discussed above, we can do numerical simulations about same-yield nuclear bombs with pure U-235 or pure Pu-239. The activities of the Xenon isotopes changing with time can be shown as below.



It is easy to see that the Xe-133 curves coincide soon, so it is difficult to get the difference from these curves. But Xe-133 can be used as a reference isotope, and we can get the ratios of other isotopes with Xe-133 as shown below.



As is shown ,it is possible to distinguish U-235 and Pu-239 with activity ratio in theory if one could detect the isotopes quickly enough. And the theoretical distinguish ability can be decided by the relative ratio of Xenon isotopes between U-235 and Pu-239, which is shown below.



Conclusion

So there is indeed possibility to identify the fissile material by the ratio of Xenon isotopes, but it requires quick response ability and high-accuracy instruments. And its real degree of confidence should be decided by the sampling method and detection accuracy. What's more, there are some other nuclides that can be used to distinguish U-235 and Pu-239, including Kr, Ba, Ru, and so on. And their isotopic ratios can be used to further confirm the result or even be used to distinguish U-235 and Pu-239 alone. But there are still some limits and the operability of these nuclides is different depending on these limits. And this requires further discussion.

E-mail: sujh06@163.com Center for Strategic Studies, CAEP, P.O. Box 8009-22, No. 6 Huayuan Road, Haidian District, 100088, Beijing, China