The need for measurement of ^{135}Xe neutron cross sections

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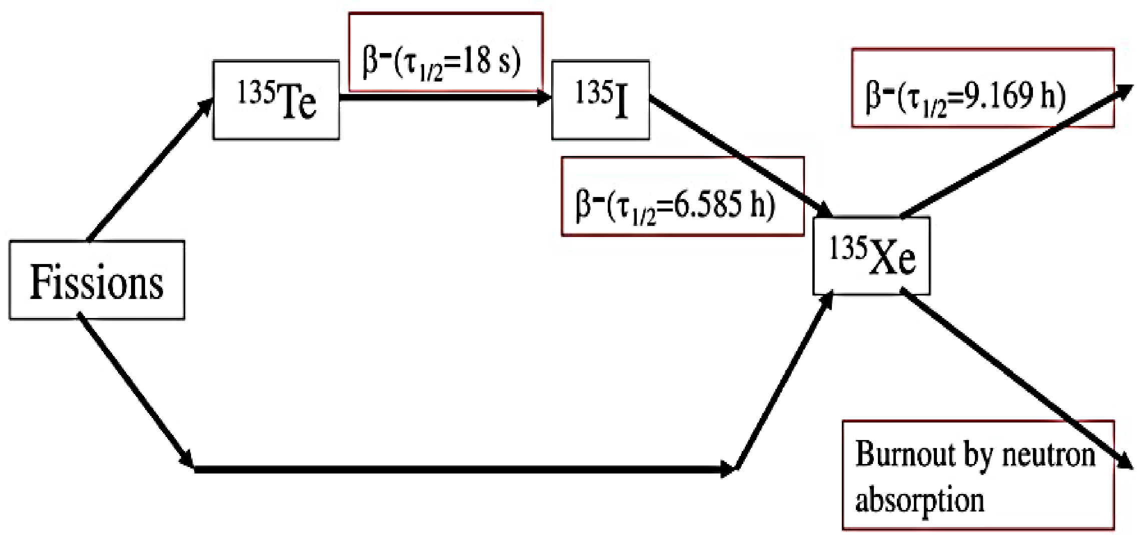
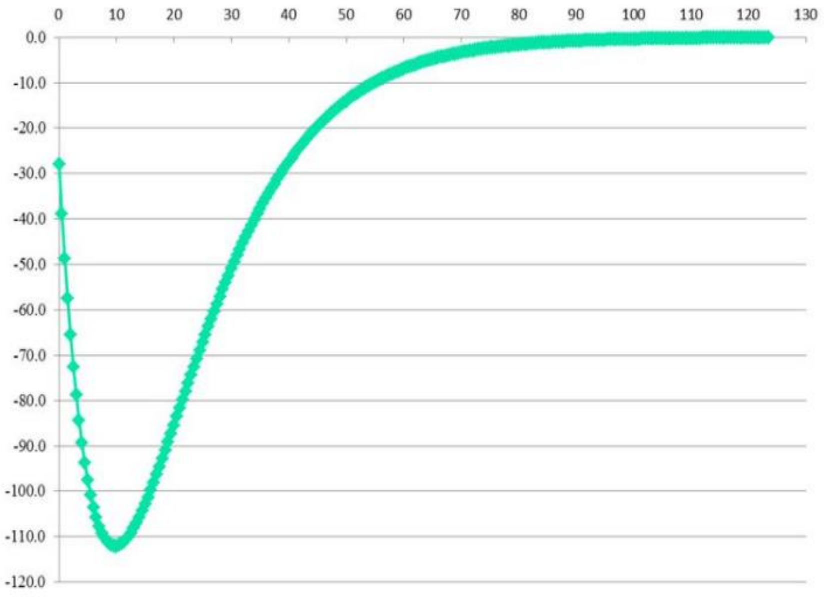
Iodine pit = Xenon poisoning

- ^{135}Xe has one of the largest capture cross section (~2.7 Megabarn) at thermal point
- It is formed in fission with main branch through ^{135}I fission product beta-decay *(Fig. taken from B. Rouben, https://slideplayer.com/slide/13215855/)*



Xenon kinetic

- **Due to decay properties of ^{135}I and ^{135}Xe and ^{135}Xe high neutron capture cross section, it may introduce very large negative reactivity sharply changing in the power transient of high flux thermal reactors**
- **Shut down from full power in CANDU reactor: -110 mK (-11% k-eff at about 10 hr after the shutdown)** ***(Fig. taken from B. Rouben, https://slideplayer.com/slide/13215855/)***
- **Usually it will require many hours of waiting for ^{135}Xe decay**



Xenon dynamic burnout

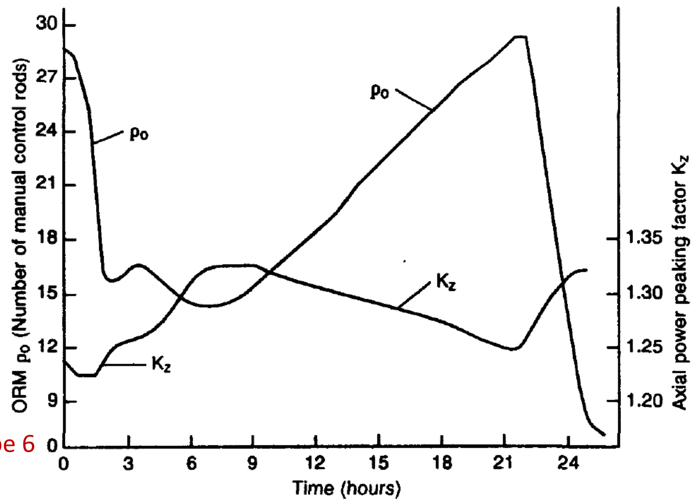
- **Because of large capture cross sections ^{135}Xe can burnout strongly in intensive neutron fields, by this introducing large positive reactivity (positive feedback mechanism)**
- **This is extremely dangerous in large RBMK reactors type of Chernobyl-4 unit. RBMK reactors without pressurized vessel can have theoretically infinite power just by increasing its size. RBMK-1000 in some estimation can be considered as the reactor with a few interfering active cores (call them "local cores")**
- **Because of long term operation at reduced (after nominal) power and even temporarily full loss of neutron power, ^{135}Xe was non-uniformly distributed through the core**

Xenon dynamic burnout

- Some “local core” may appear without effective control of neutron power, because 1 hour before the accident the switchover was done from local power control to main range (external) power (~ neutron flux) control
- Some “local core” (especially in the lower part of the core) may appear practically without any control, because before the explosion only 8 effective control roads (or 45 physical, mostly in the upper position of the core) regulated the criticaality
- Simple estimation shows, that due to dynamic ^{135}Xe burnout, a “local core” may become supercritical within a few minutes

Xenon dynamic burnout

- The drop of Operating Reactivity Margin (ORM=ρ_0, taken from Fig. II-4 INSAG-7) from about 28 to 15 (allowed by the Manual) and then below 8 is mainly due to ^{135}Xe poisoning. This is equivalent of about -15βeff or about 90 mK for this reactor on my estimation
- Without Local Power Control and with Positive Feedback, the Xenon dynamic burnup may lead to introduction of the local positive reactivity and the neutron field (power) excursion in the "sub-core" (some quadrant which was a center of the energy release in thermal and then in nuclear explosion)
- The temperature coefficient of reactivity for ^{135}Xe and his volatile properties may also play a role in the dynamic of accident development



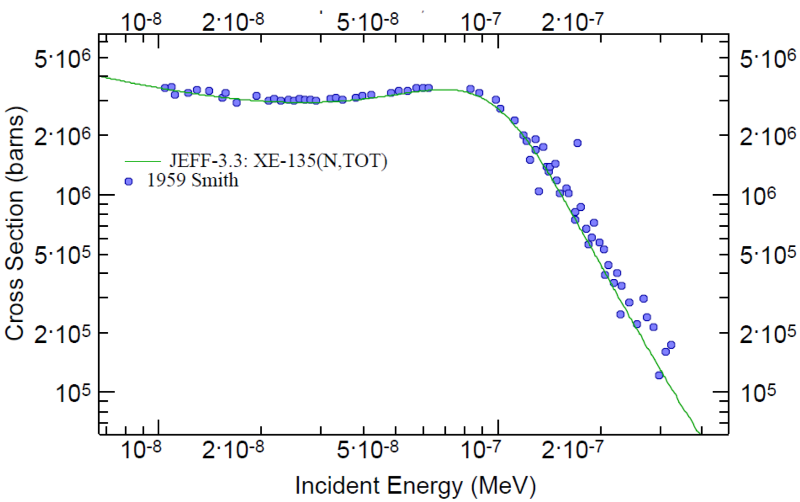
Should be 6

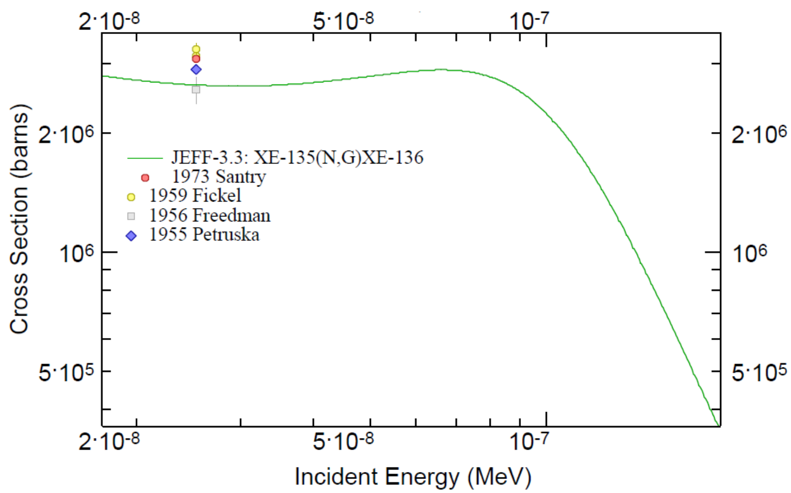
Conclusion

- Good knowledge of capture cross section in the energy range below few eV is extremely important for safety of thermal reactors
- Or we must rely mostly on engineering solutions

Xenon neutron cross sections

- Only 6 EXFOR entries contain the info about ^{135}Xe cross sections
- All measurements done between 1955 and 1959 (one work for SACS in 1973)
- Total cross section and the parameters of the resonance which determines the cross section in the thermal energy range are obtained in one (with later updating) measurement
- Experimental MACS capture cross sections for few temperatures are available



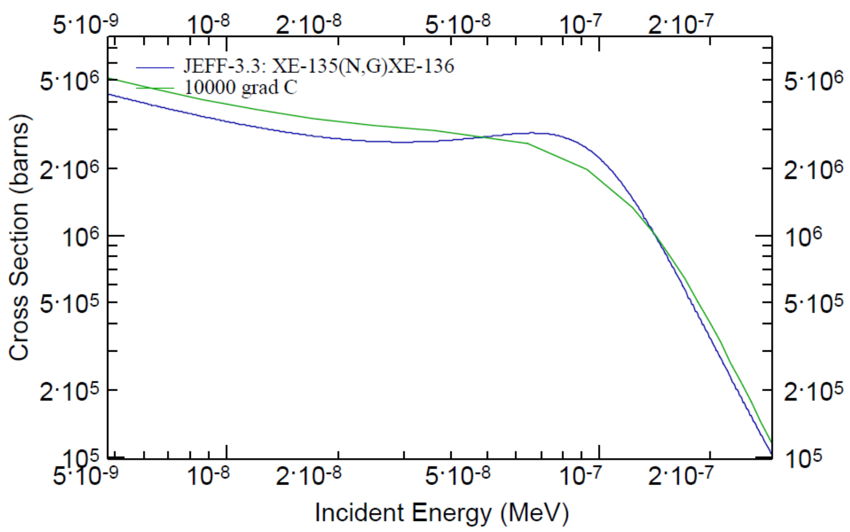


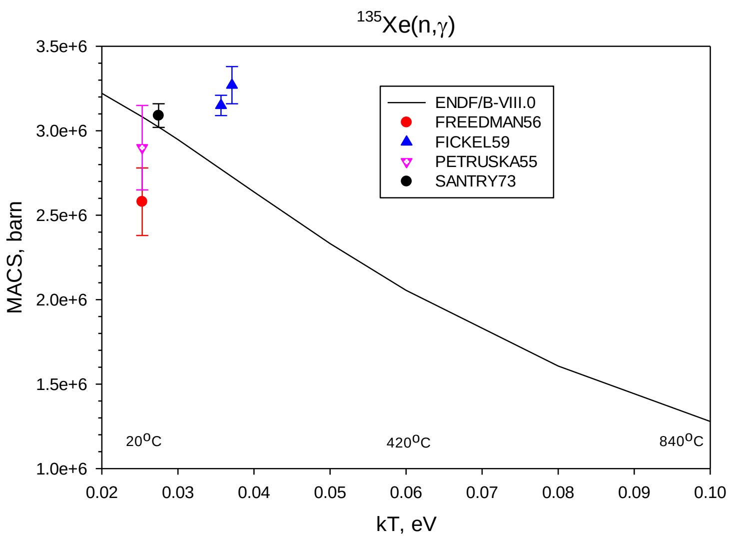
Xenon neutron cross sections

- **Temperature of the fuel and moderator can influence at the xenon poisoning criticality coefficient in the range of working temperatures**

Doppler broadening has small influence at the xenon poisoning temperature reactivity coefficient in the range of working temperatures

Neutron temperature has large influence at the xenon poisoning temperature reactivity coefficient in the range of working temperatures. It is a positive feedback process





Conclusion

- **Our present knowledge ^{135}Xe cross sections is based at a single total cross section measurement**
- **4 MACS capture cross section measurements for the limited range of temperatures have a large spread and are poorly consistent with the values obtained from evaluated data**
- **Good knowledge of the $^{135}Xe(n,\gamma)$ cross section below 0.1 eV is needed for kinetic and dynamic processes caused by xenon poisoning**
- **It is proposed to include in the HPRL request at the measurements of ^{135}Xe total cross section in the energy range below 0.1 eV and MACS in the range of kT=0.0253 – 0.1 eV energy range**