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Enhancing nuclear safety

EVIDENCE OF A CRITICALITY ACCIDENT OCCURRING WITH SPENT FUELS: BASIC CONSIDERATIONS AND LESSONS LEARNED FROM THE FUKUSHIMA ACCIDENT

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« Tellurium 129 presence is proof of inadvertent recriticality at Fukushima »

April 2011

A criticality accident during Fukushima

- Preliminary questions:
 - Is it credible?
 - Is it relevant compared to other hazards?
 - Who cares?

- Possible evidence of a criticality accident occurring with spent fuels ?

Possible evidence ?

- Fission products (FP)
 - To be detectable
 - To be produced in a significant quantity during the criticality accident to not be confused with the “normal” inventory

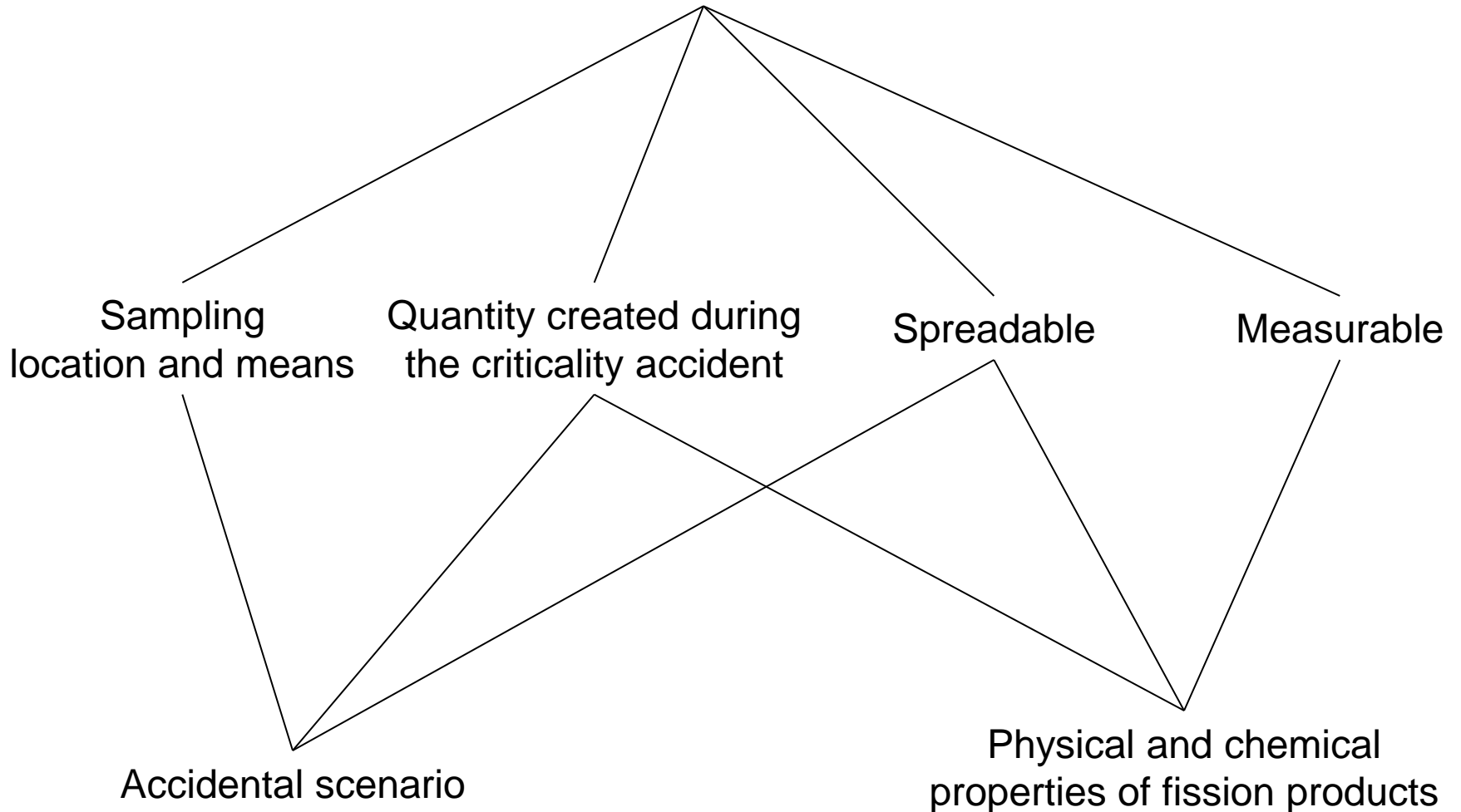
Fukushima Daiichi Nuclear Power Station: the result of measurement of sub drain

	Unit 1 (collected at 11:10 am, March 30 th)	Unit 2 (collected at 11:20 am, March 30 th)	Unit 3 (collected at 11:30 am, March 30 th)	Unit 5 (collected at 10:30 am, March 30 th)	Unit 6 (collected at 10:40 am, March 30 th)
	Below the detection limit	About 3.6×10^1	Below the detection limit	Below the detection limit	Below the detection limit
Sb-95 (About 35 days)	Below the detection limit	Below the detection limit	Below the detection limit	Below the detection limit	About 8.1×10^1
Te-129 (About 70 minutes)	About 1.2×10^2	Below the detection limit	Below the detection limit	Below the detection limit	Below the detection limit
Te-129m (About 34 days)	About 8.7×10^0	About 1.7×10^0	Below the detection limit	Below the detection limit	About 1.3×10^0
I-131 (About 8 days)	About 4.3×10^0	About 8.0×10^0	About 2.2×10^0	About 1.9×10^0	About 2.0×10^0
I-132 (About 2 hours)	About 8.3×10^0	Below the detection limit	About 1.3×10^0	Below the detection limit	About 1.8×10^{-1}
Te-132 (About 3 days)	About 3.0×10^0	About 3.9×10^0	About 1.4×10^0	About 1.0×10^0	About 6.0×10^{-1}
Cs-134 (About 2 years)	About 5.2×10^0	About 7.0×10^0	About 1.0×10^0	About 2.5×10^0	About 4.7×10^0
Cs-136 (About 13 days)	About 3.9×10^0	About 6.1×10^0	About 9.4×10^0	About 2.7×10^0	About 3.9×10^0
Cs-137 (About 30 years)	About 6.3×10^0	About 6.3×10^0	About 1.0×10^0	About 2.7×10^0	About 4.9×10^0
La-140 (About 2 days)	About 3.3×10^0	Below the detection limit	About 7.3×10^0	Below the detection limit	About 4.1×10^0

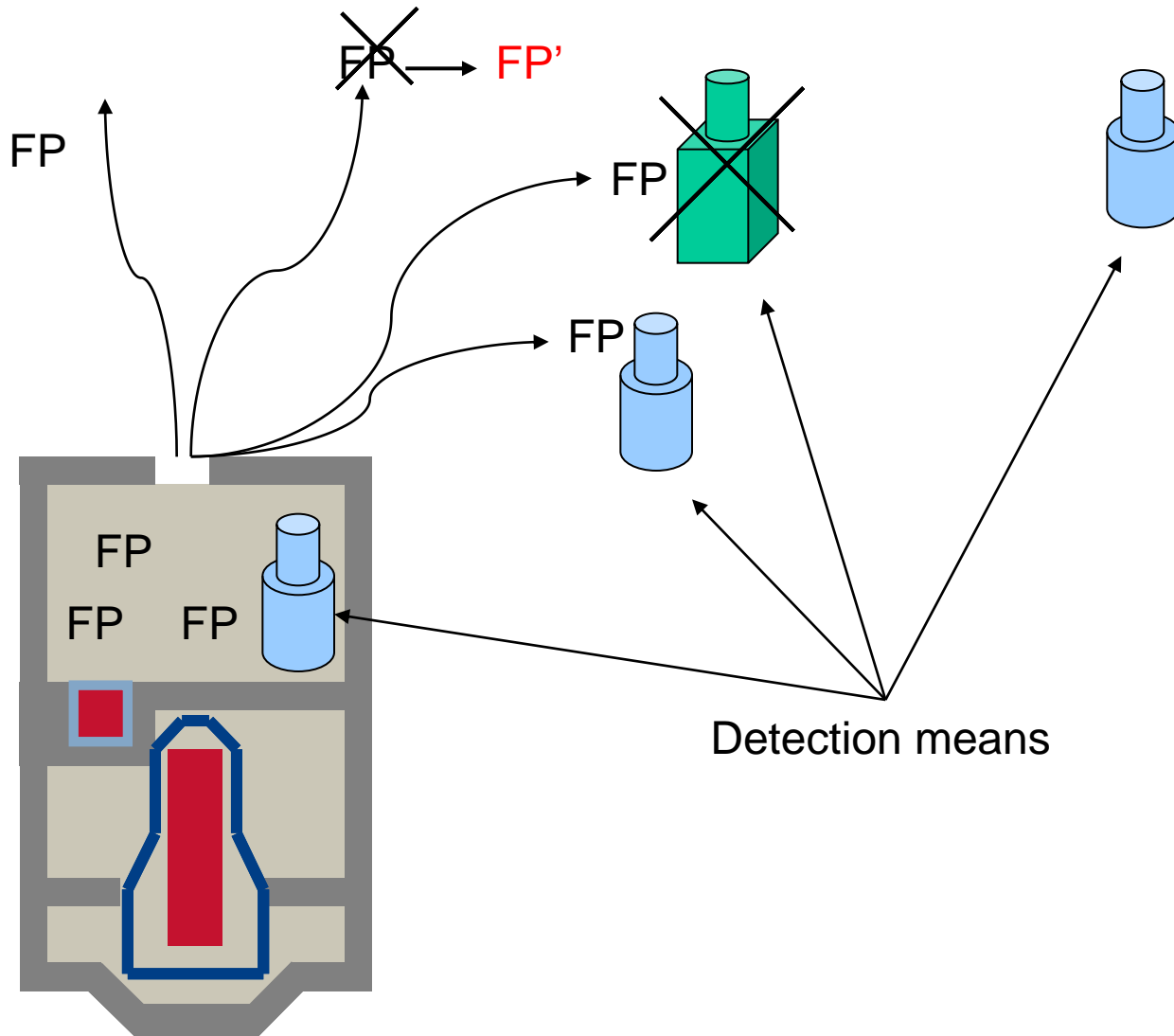
- Fukushima accident
 - Fission products were measured
 - Evidence of a criticality accident ?
- Our article’s philosophy
 - Reflection on important parameters for an adequate FP
 - Properties of fission products (physical and chemical)
 - Accidental scenario (all events and features of the facilities that are involved in a crisis like Fukushima)

Important parameters for an adequate FP

Detection of a fission product

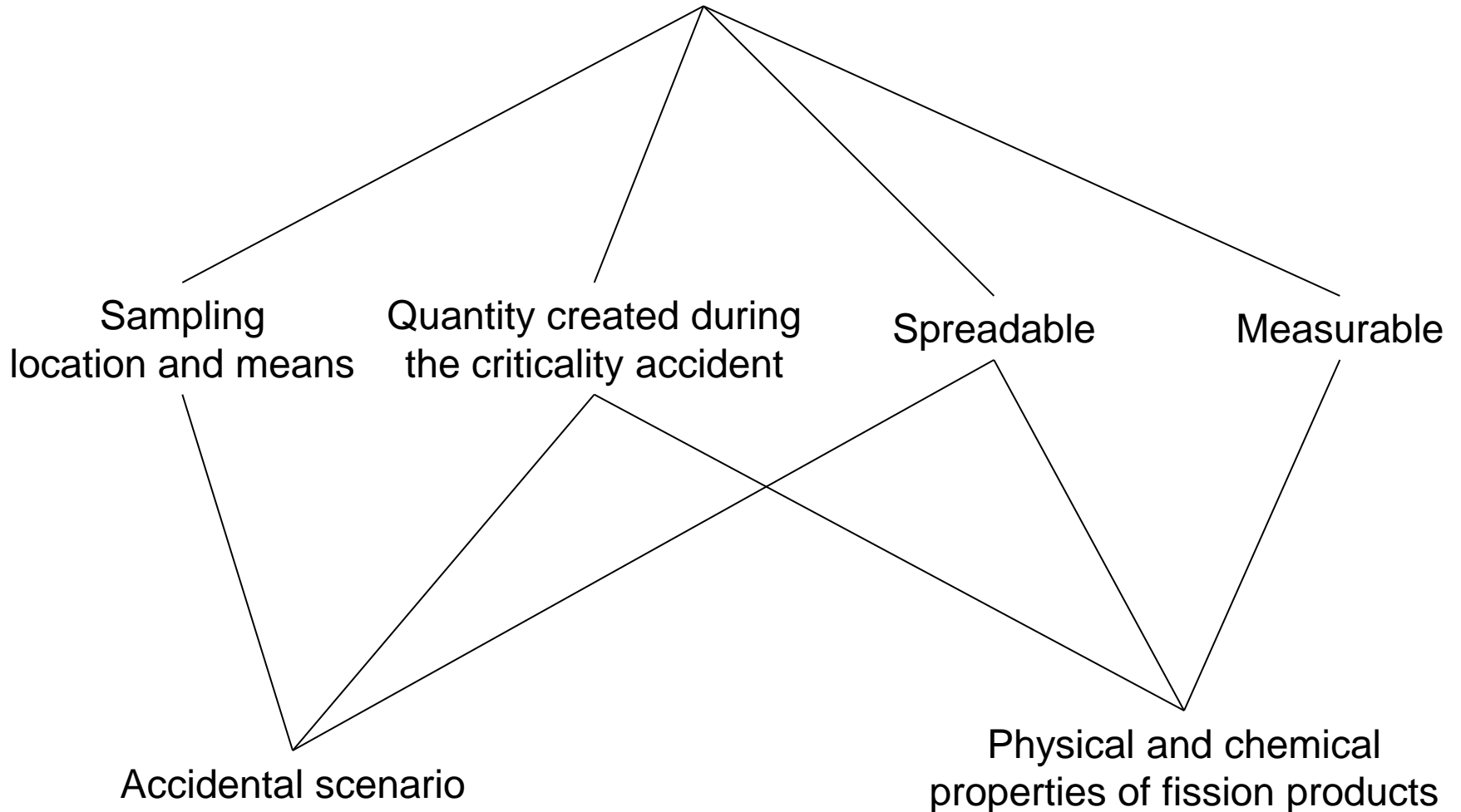


Detection of a fission product



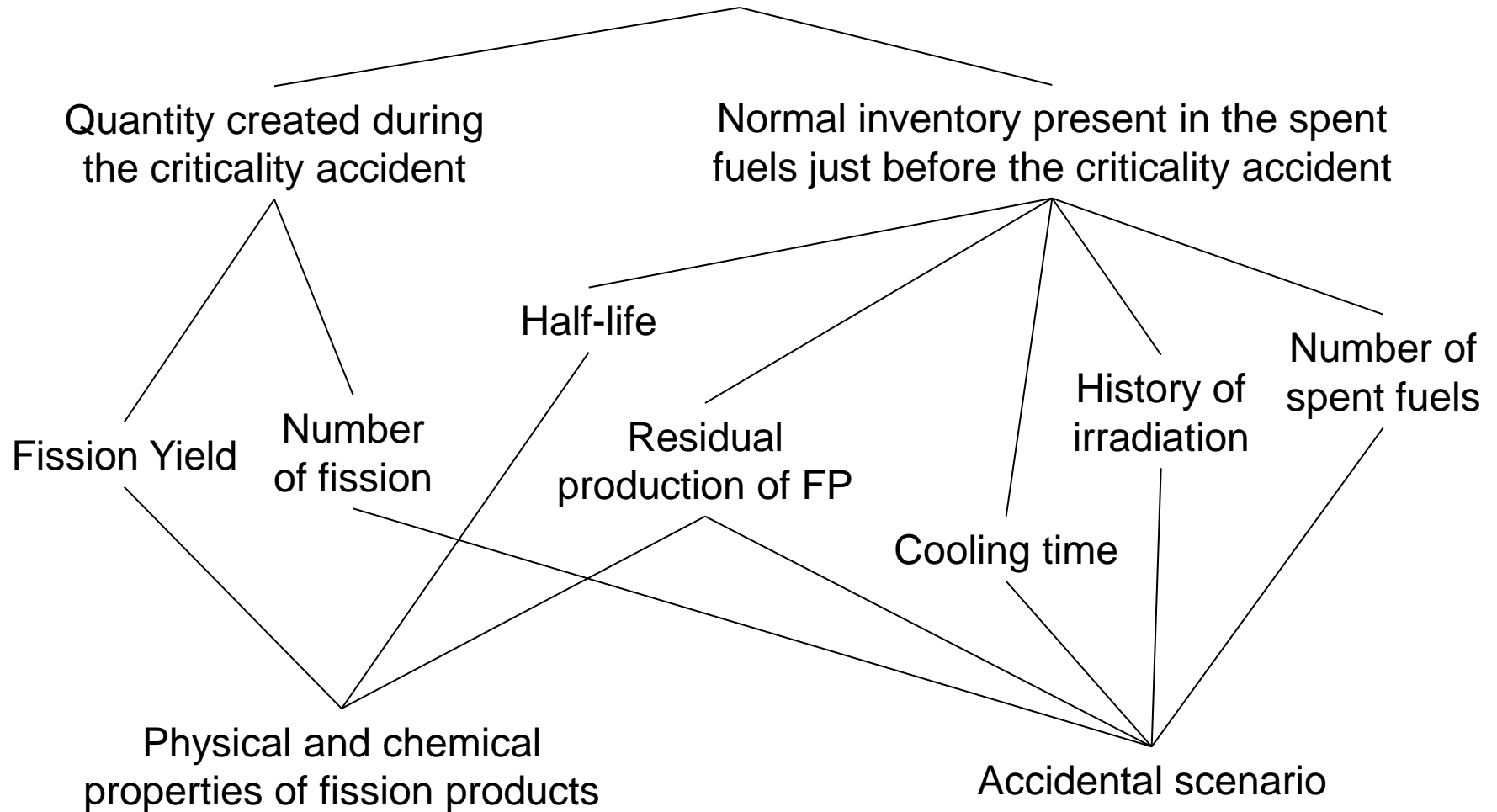
Important parameters for an adequate FP

Detection of a fission product

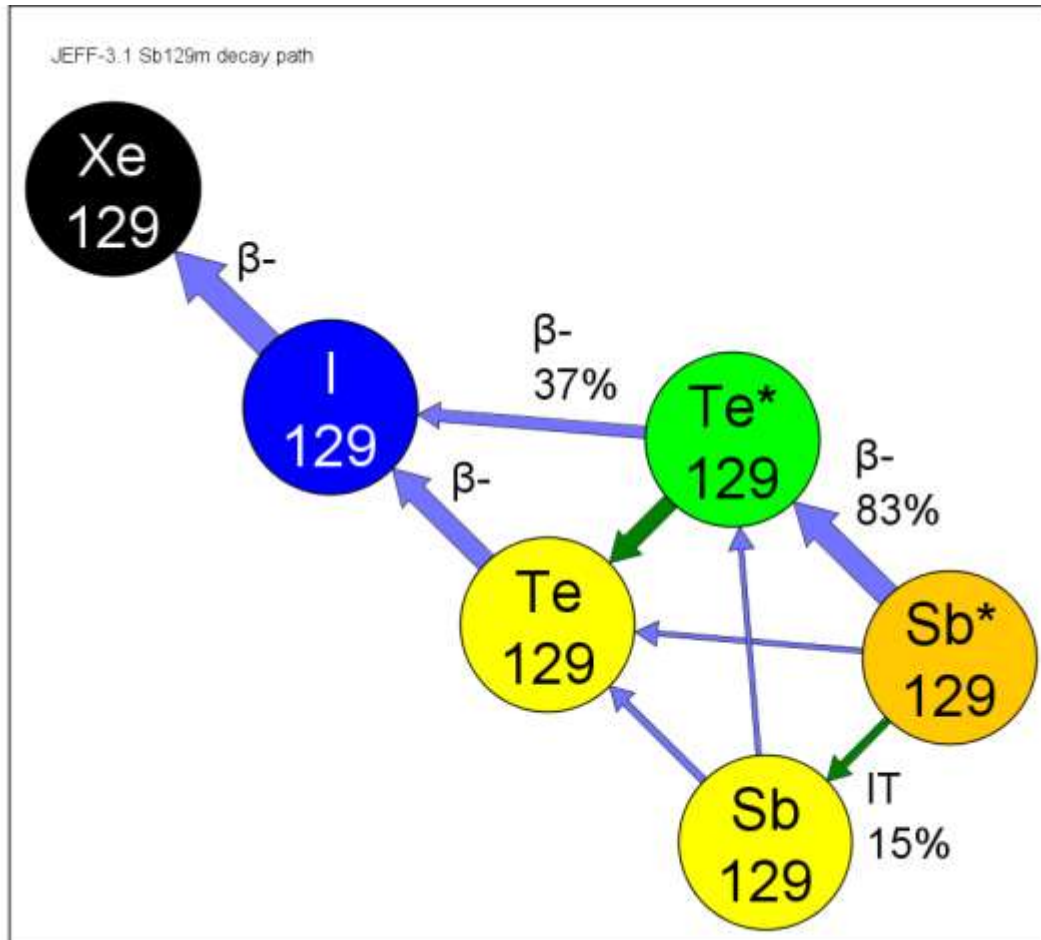


Important parameters for an adequate FP

Abnormal production of a fission product during the criticality accident



Half life (... and the decay path)



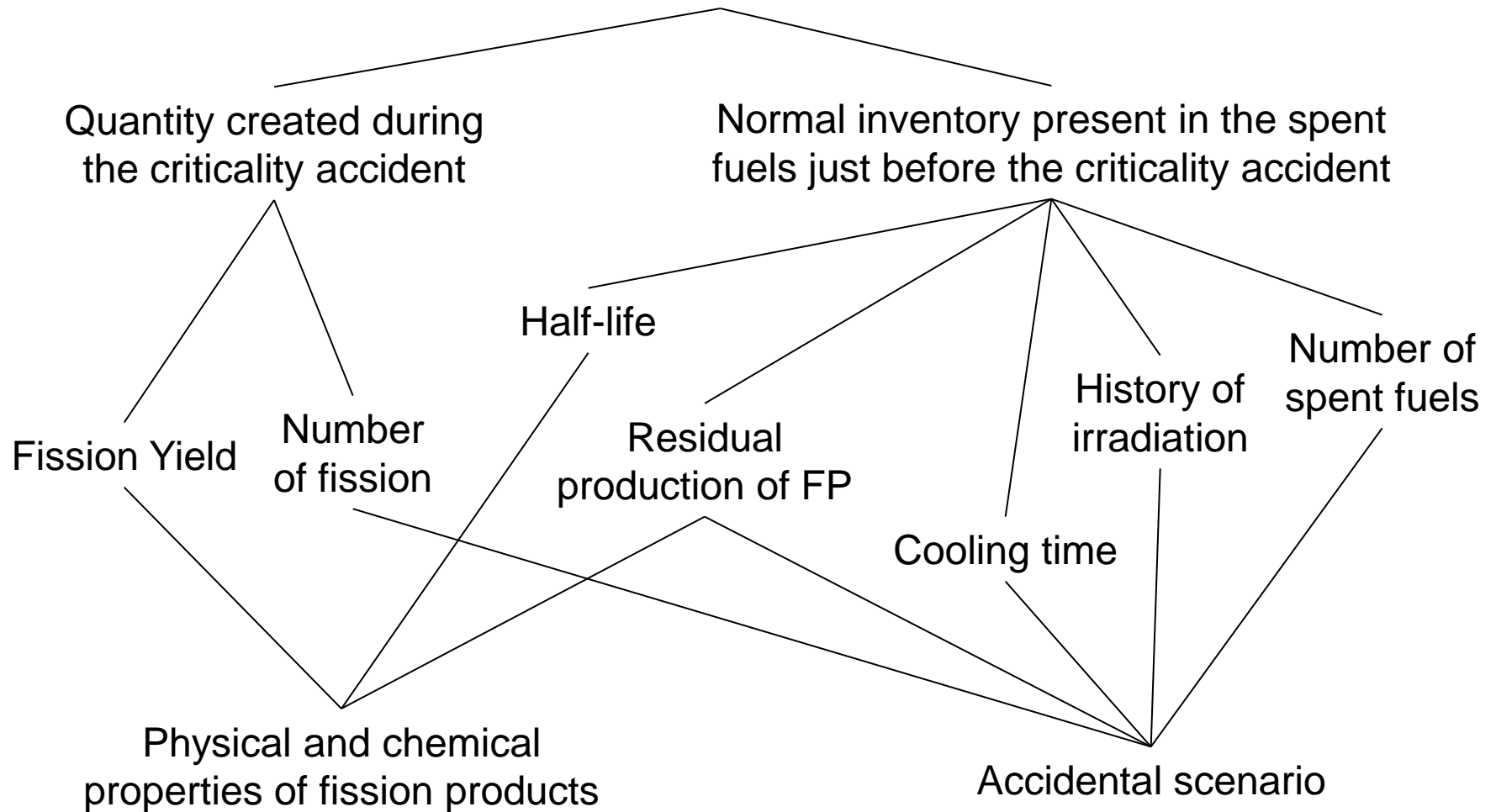
$t_{1/2} (^{129}\text{Te}) = 1,16$ hour

$t_{1/2} (^{129m}\text{Te}) = 33,6$ days

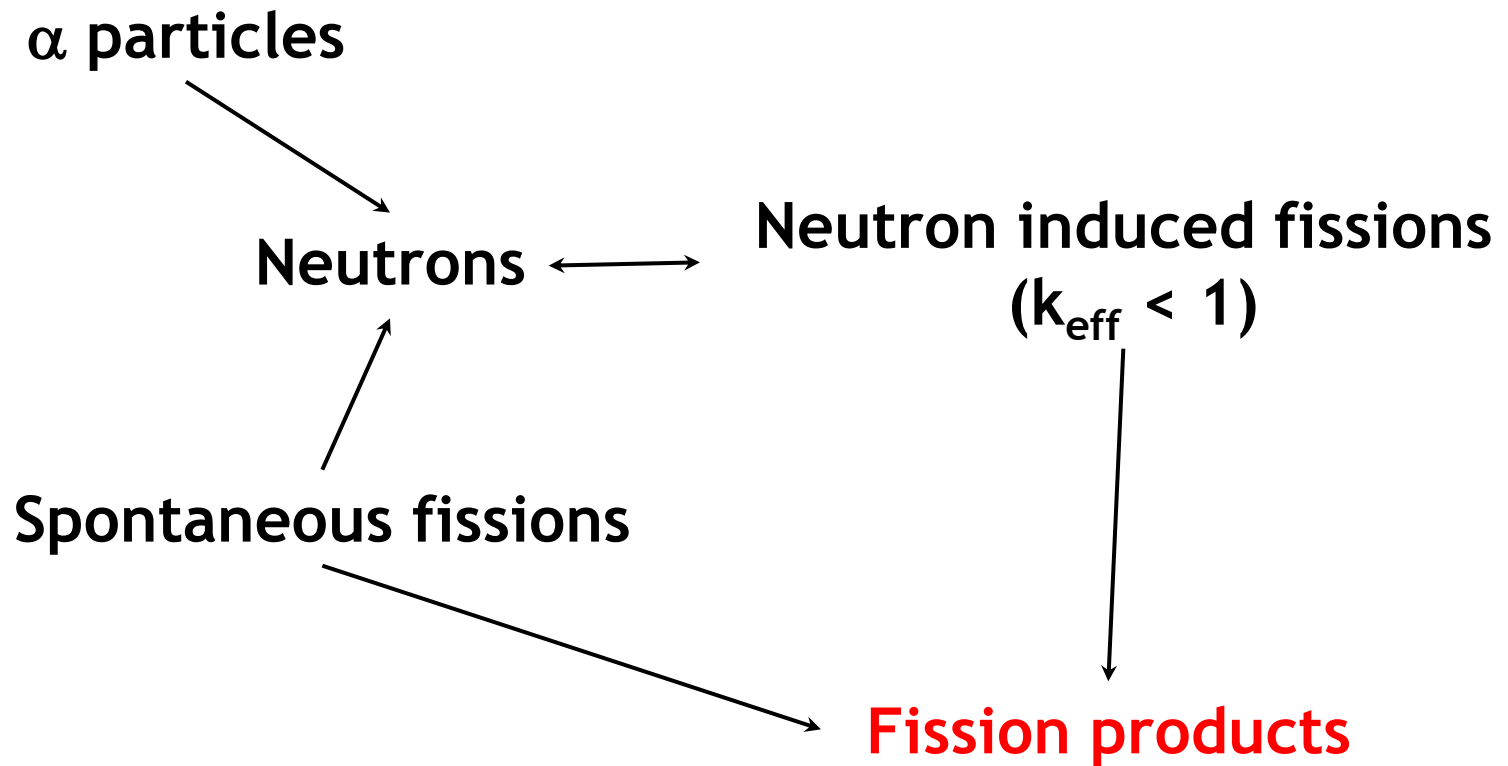
« In April 2011, ^{129}Te presence **was not** proof of inadvertent recriticality at Fukushima »

Important parameters for an adequate FP

Abnormal production of a fission product during the criticality accident



Residual production of FP

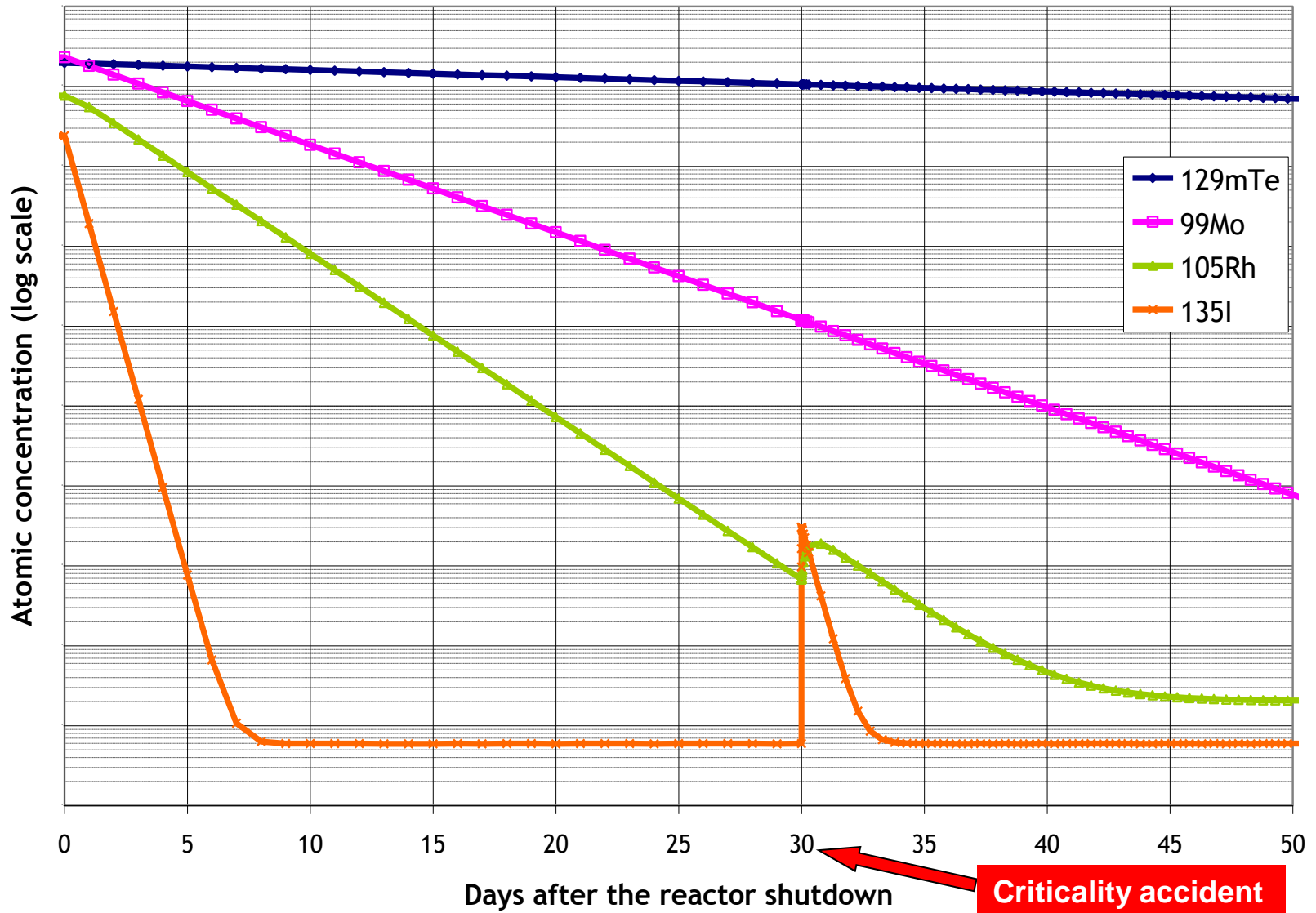


Example 1 / 3

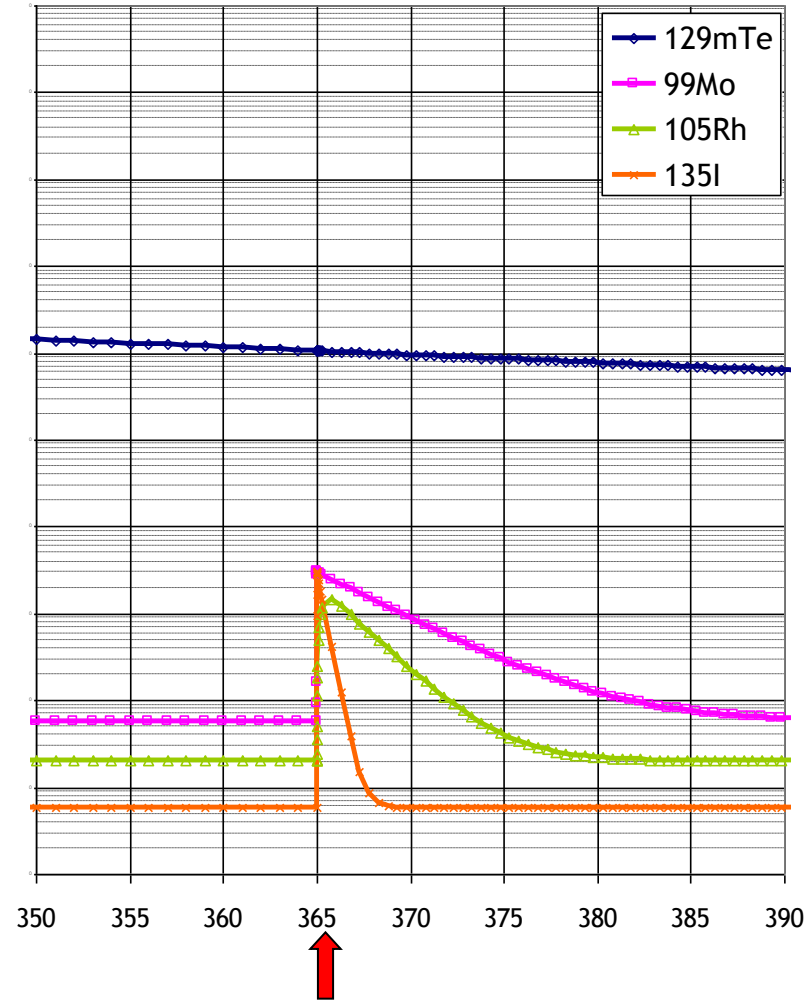
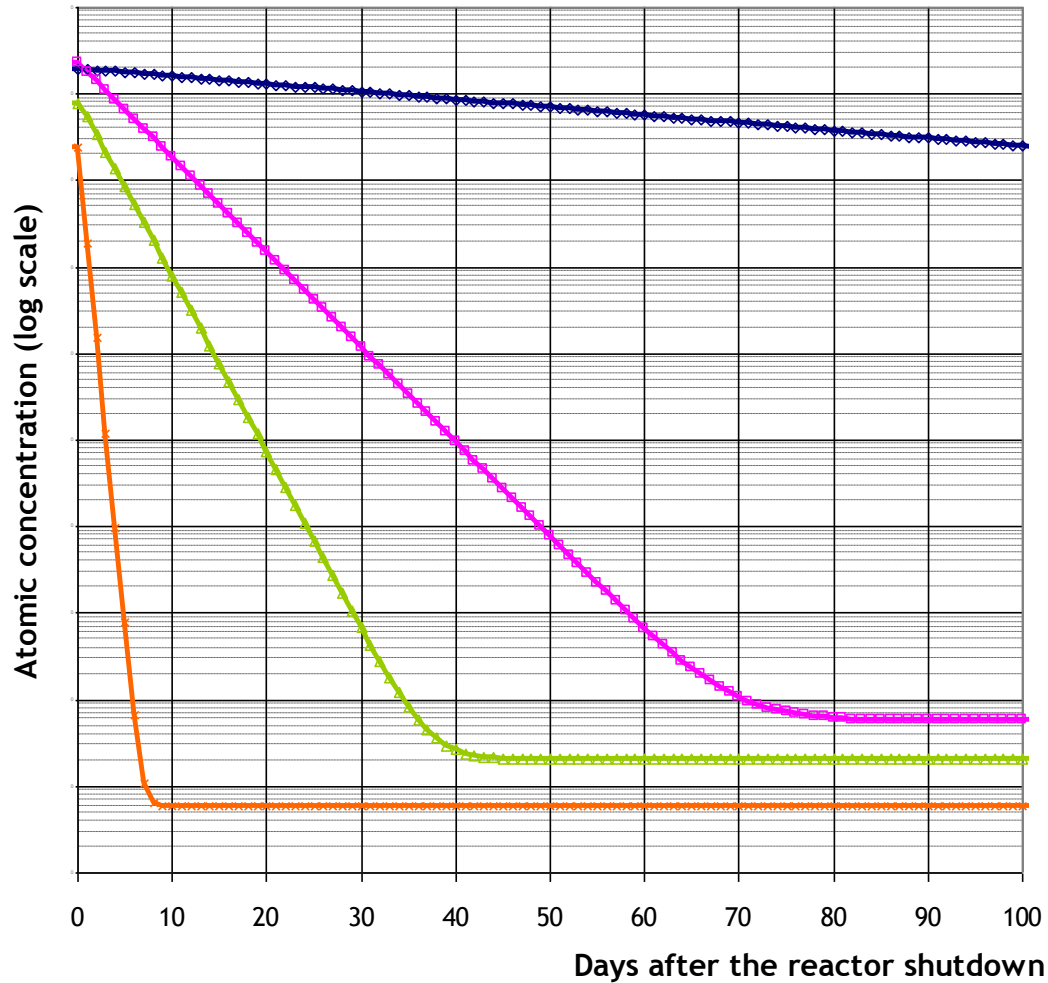
- Illustration of the abnormal production of a fission product during the criticality accident
- A textbook case
 1. A PWR 17 x 17 with a typical 35 GWd/t irradiation
 2. A criticality accident occurring either 30 or 365 days after the end of irradiation in the reactor core (“reactor shutdown”)
- Code used
 - VESTA: IRSN Monte-Carlo depletion interface code
- Parameter observed
 - Time evolution of the atomic concentrations of a single UO_2 pin



Example 2/3



Example 3/3



Conclusion

- New topic: this article is an **account** of our experience during Fukushima accident
 - Some FP may be possible evidence of a criticality accident
- **All parameters** shall be taken into account to give an evaluation
 - Easier to discard a candidate than select one appropriate
 - Absolute conclusion will be always difficult
- Parameters linked to the **detection of fission products** should be cautiously evaluated
 - Collaboration with other experts (detection, release, etc.)
 - Suggestion: measurement of **isotopes ratio** of same elements

Thank you for your attention !