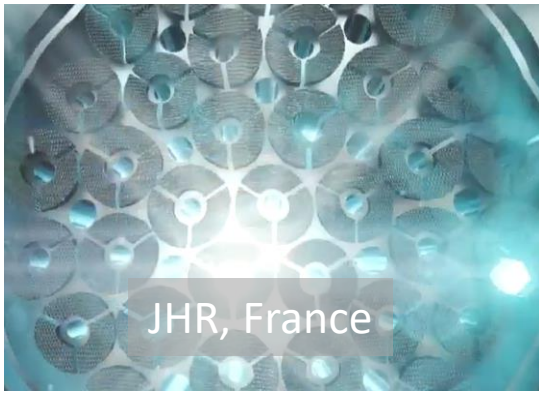
DE LA RECHERCHE À L'INDUSTRIE

CADARACHE


# SENSITIVITY ANALYSIS OF AN ADVANCED MEASUREMENT METHOD FOR THERMAL NEUTRONS ABSORBERS DETECTION IN IRRADIATED BERYLLIUM.

M. WRÓBLEWSKA, D. BLANCHET, A. LYOUSSI, P. BLAISE,
Z. MARCINKOWSKA, A.BOETTCHER, J. JAGIELSKI,

**MAŁGORZATA WRÓBLEWSKA NCBJ - CEA – AMU**

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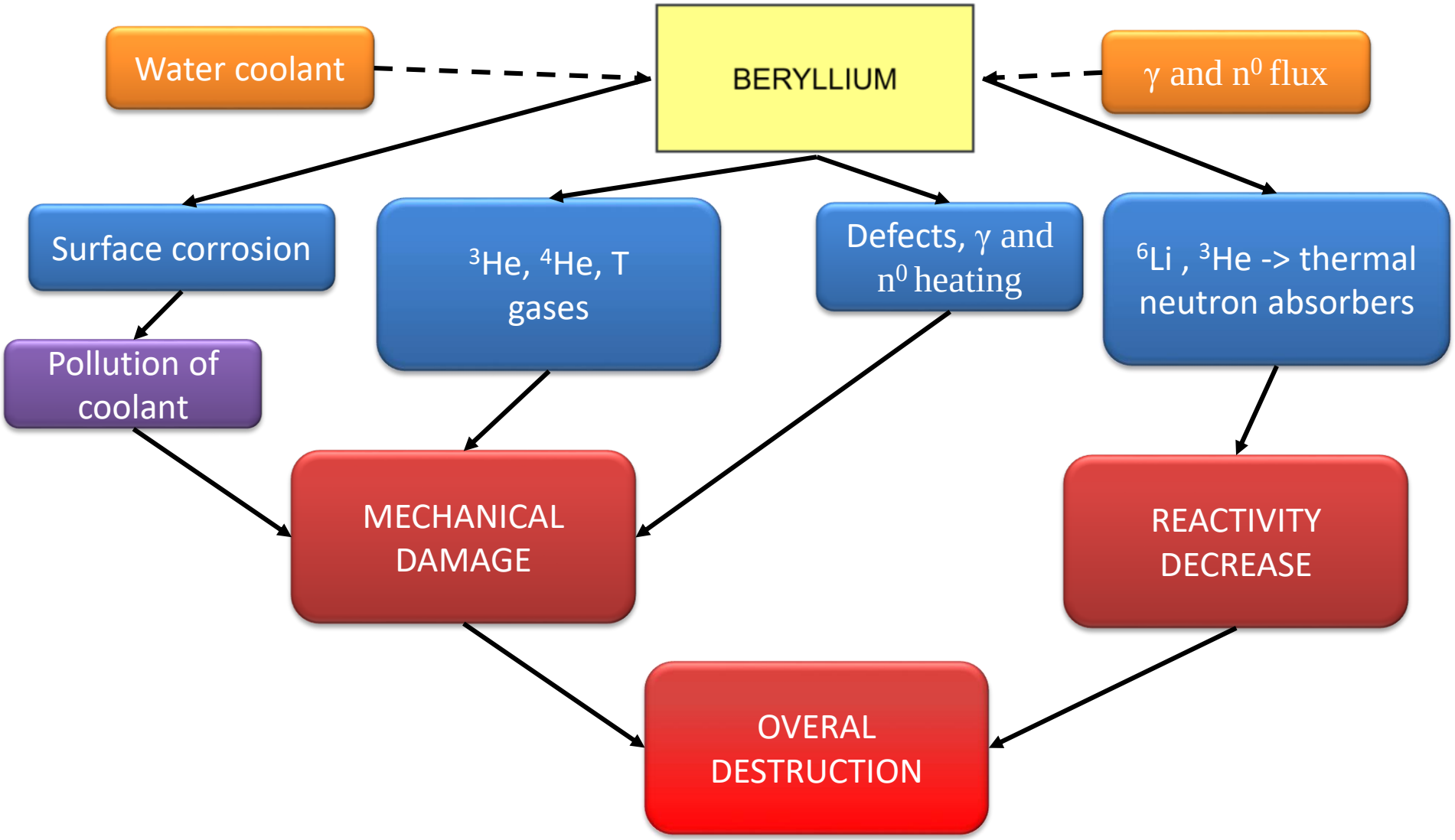
ANIMMA 2021 Prague, Wednesday, June 23th2021

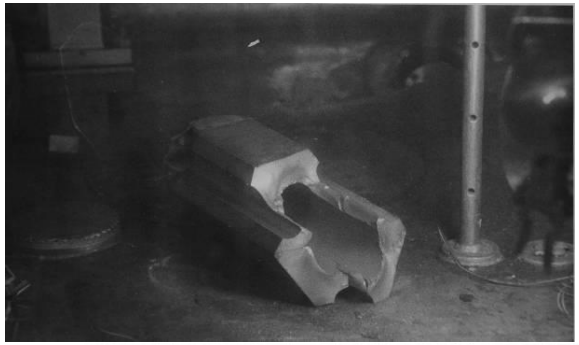
- Poisoning effect in MTRs
- Experimental setup
- Sensitivity analysis
- Conclusion

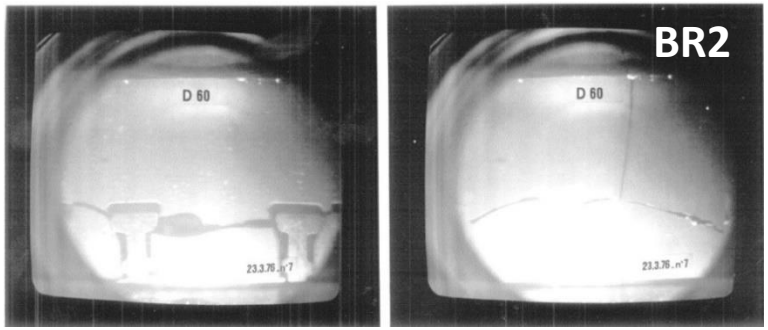
# Beryllium damage mechanisms



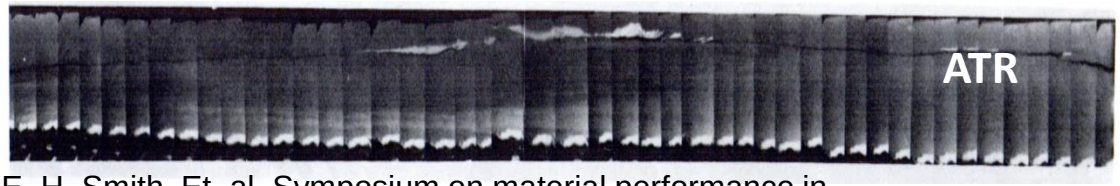
# Mechanical failure examples

**View of the SM and MIR reactors beryllium blocks irradiated to fast neutron fluence of F~6·10$^{22}$ cm$^{-2}$**



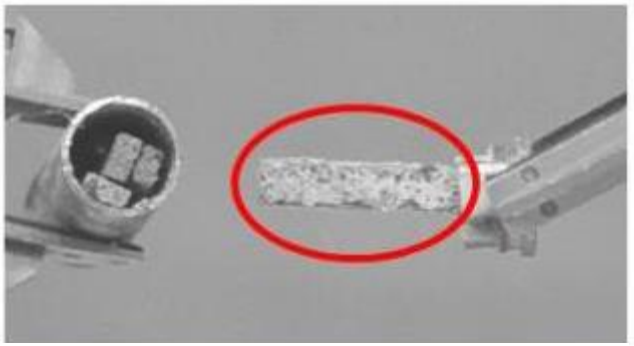



F. Joppen, E. Koonen, S. Van Dijck. International Atomic Energy Agency (IAEA)




E. H. Smith. Et. al. Symposium on material performance in operating nuclear systems. August 1973.

V. Chakin et al., 1st International Symposium on Material Testing Reactors. Japan. 2008.



**JMTR samples corrosion**

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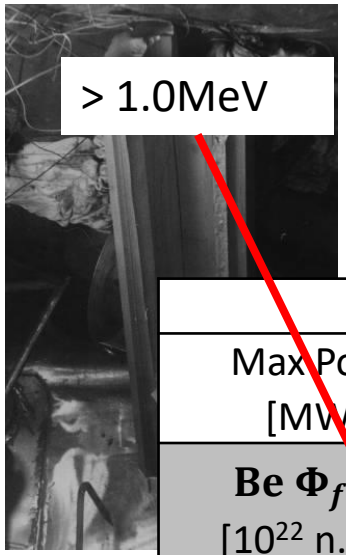
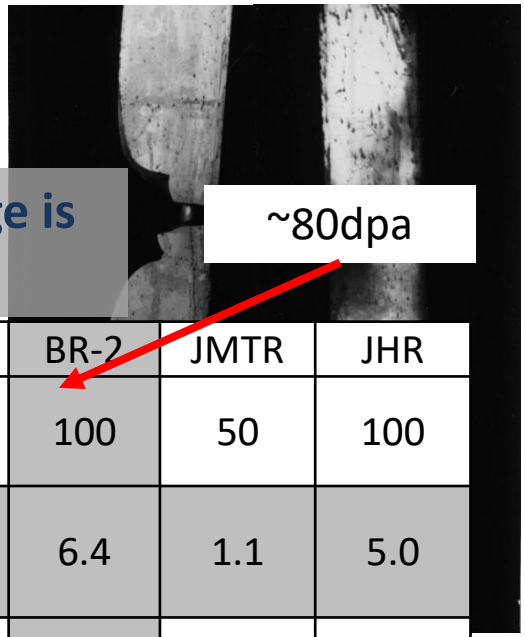


> 1.0MeV

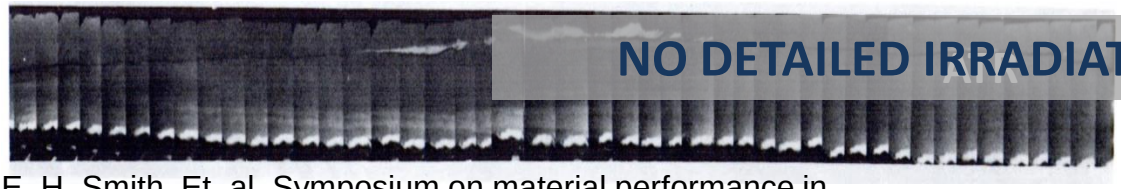


~80dpa

**The main criteria for mechanical damage is FAST NEUTRON FLUENCE**

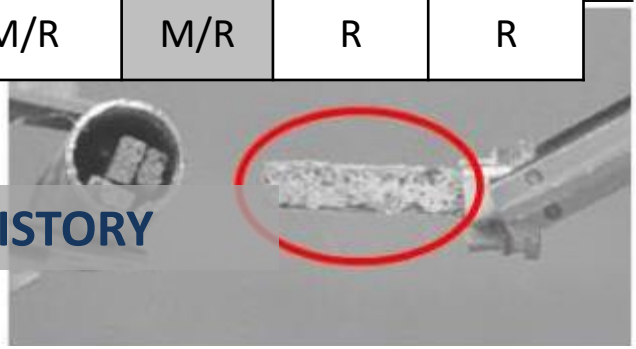
| | SAFARI | ATR | HFIR | MARIA | MIR | BR-2 | JMTR | JHR |
|---|---|---|---|---|---|---|---|---|
| Max Power [$MW_{th}$] | 20 | 250 | 85 | 30 | 100 | 100 | 50 | 100 |
| Be $\Phi_{f\,max}$ [$10^{22}$ n.cm$^{-2}$] | 0.9 | 5.5 | 3.4 | 2.0 (>0.5MeV) | 6 .0 (>0.1MeV) | 6.4 | 1.1 | 5.0 |
| Be function | R | R | R | M | M/R | M/R | R | R |

F. Joppen, E. Koonen, S. Van Dijck. International Atomic Energy Agency (IAEA)



**NO DETAILED IRRADIATION HISTORY**

E. H. Smith. Et. al. Symposium on material performance in operating nuclear systems. August 1973.



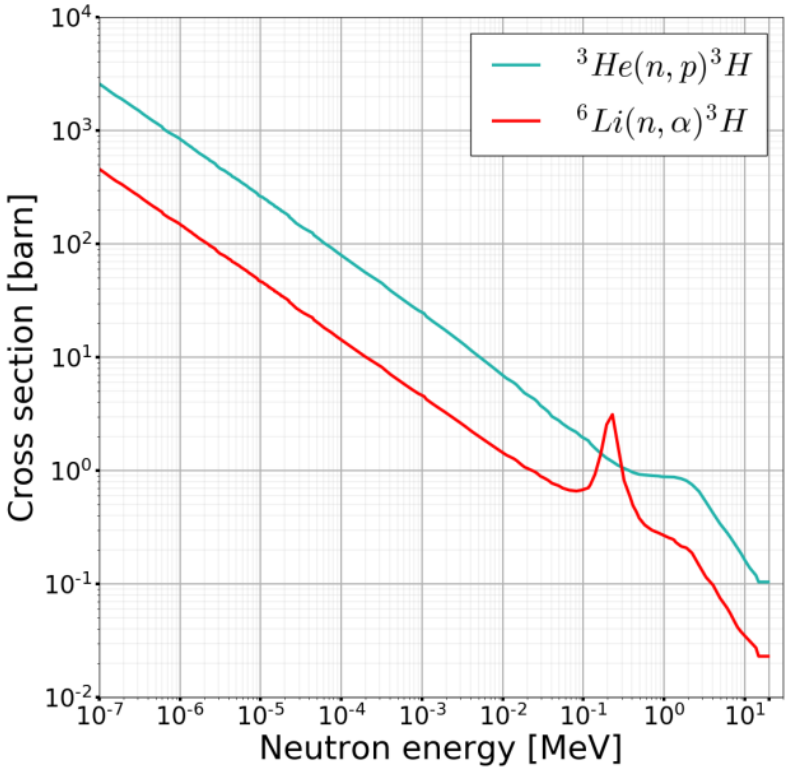
**JMTR samples corrosion**

# Poisons production (n,α)

$$\left.\begin{array}{l} {}^{9}Be + n\ (4-10\ MeV) \\ {}^{9}Be + n\ (2-4\ MeV) \\ {}^{9}Be + n\ (1-2\ MeV) \end{array}\right\} \xrightarrow[85\ mb]{10\ mb} {}^{10}Be^{*} \longrightarrow {}^{4}He + {}^{6}He - 0.64\ MeV$$

$$^{6}Li + \beta^{-} \xleftarrow{0.8\ s} {}^{6}He$$

**Fast neutrons**




**POISONS**

$$^{6}Li + n(th) \xrightarrow{950\ b} {}^{4}He + {}^{3}H + 4.7\ MeV$$

$$^{3}H \xrightarrow{12.3\ yr} {}^{3}He + \beta^{-}$$

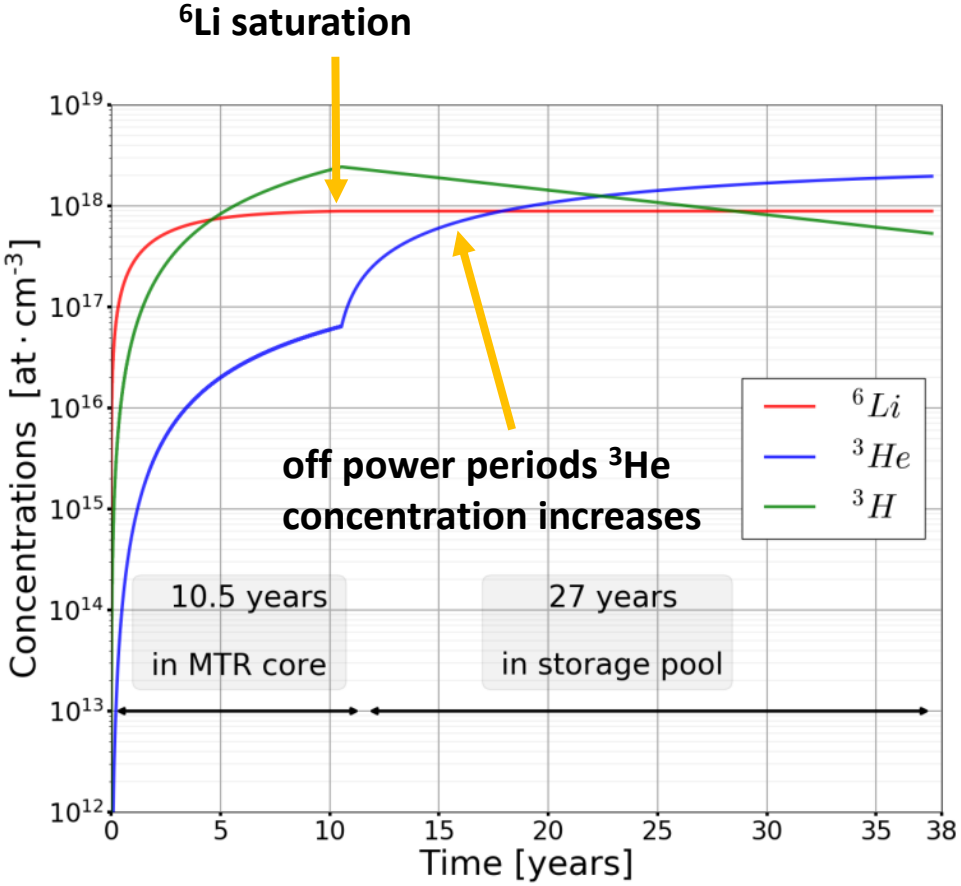
$$^{3}He + n(th) \xrightarrow{5327\ b} {}^{3}H + p$$

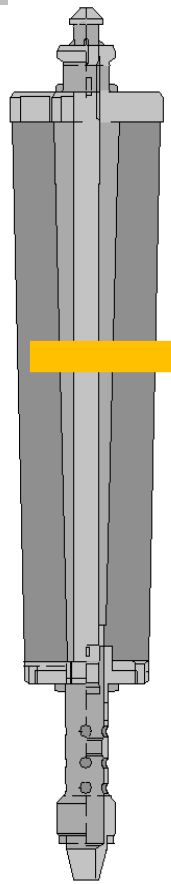
$$^{3}He \xrightarrow{0.05\ mb} {}^{4}He$$

**Thermal neutrons**

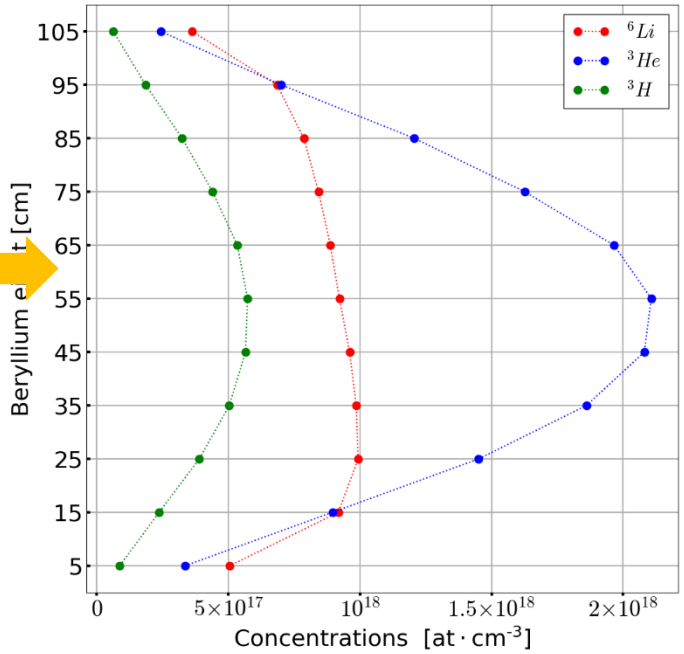
# Realistic scenario in MARIA

**1 CYCLE = 100h on power + 68h off power**
**10.5 YEARS OPERATION + 27 YEARS OFF**



After 37.5 years

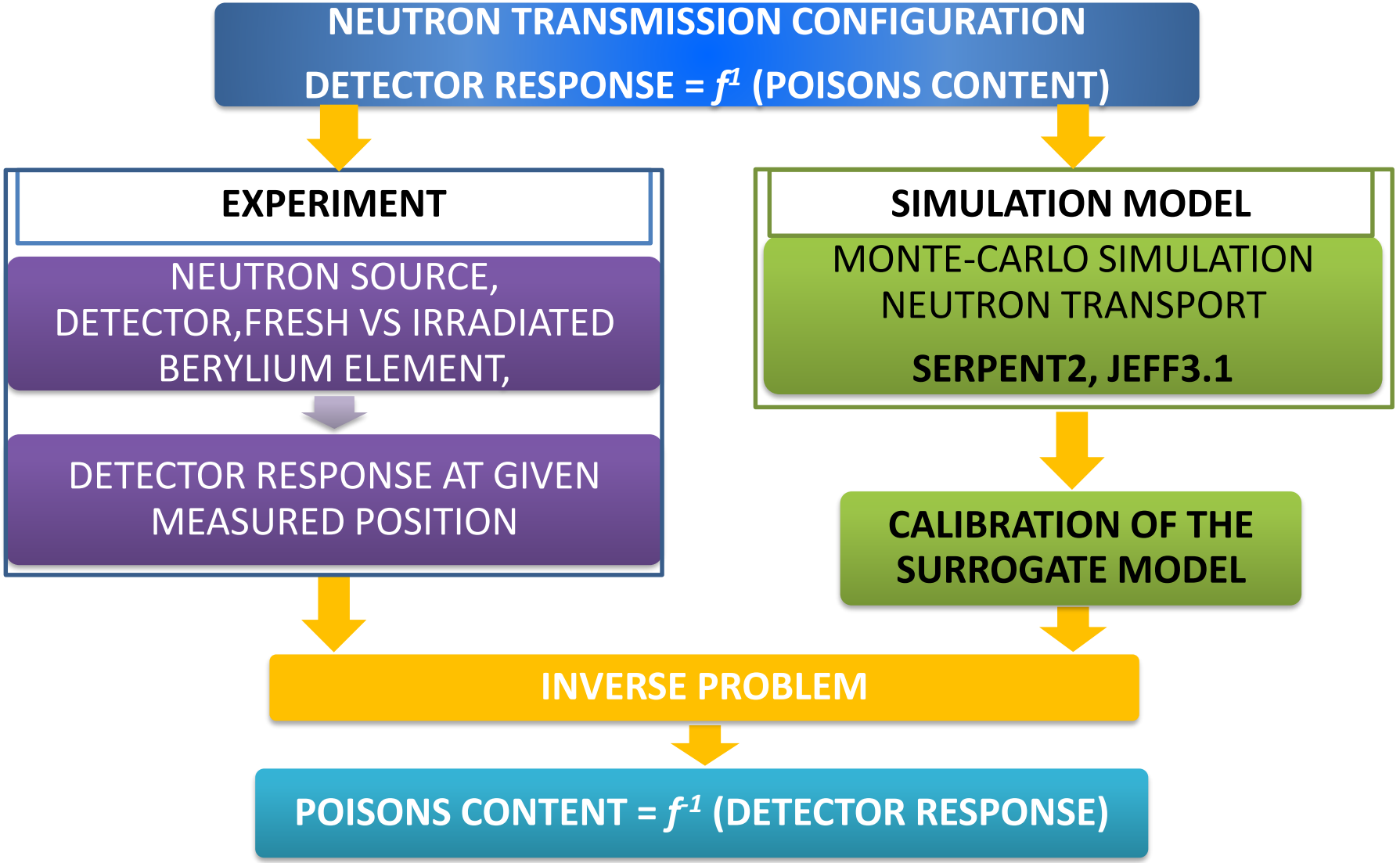



**SPECIFIC ACTIVITY:**
**~1GBq /1g of Be**

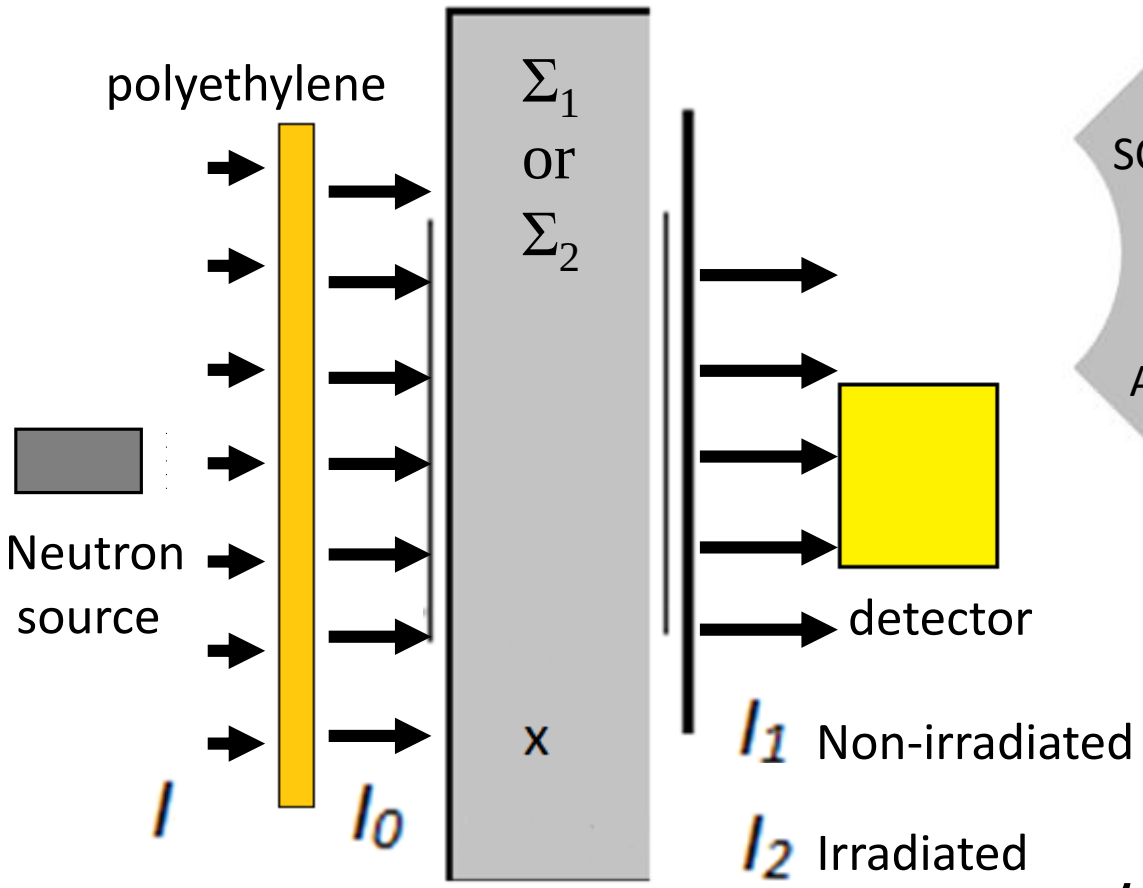
Simplifying assumptions; for detailed information: neutronic tools

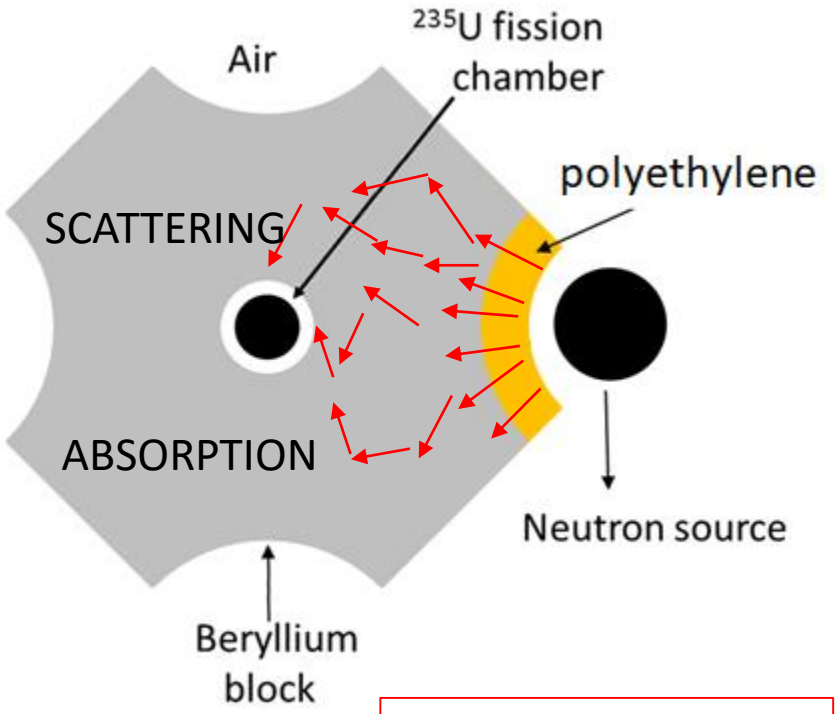
- Poisoning effect in MTRs
- Experimental setup
- Sensitivity analysis
- Conclusion

# Experiment, analysis and validation



MEASUREMENT OF THERMAL NEUTRONS ATTENUATION IN **FRESH** /**IRRADIATED** BERYLLIUM

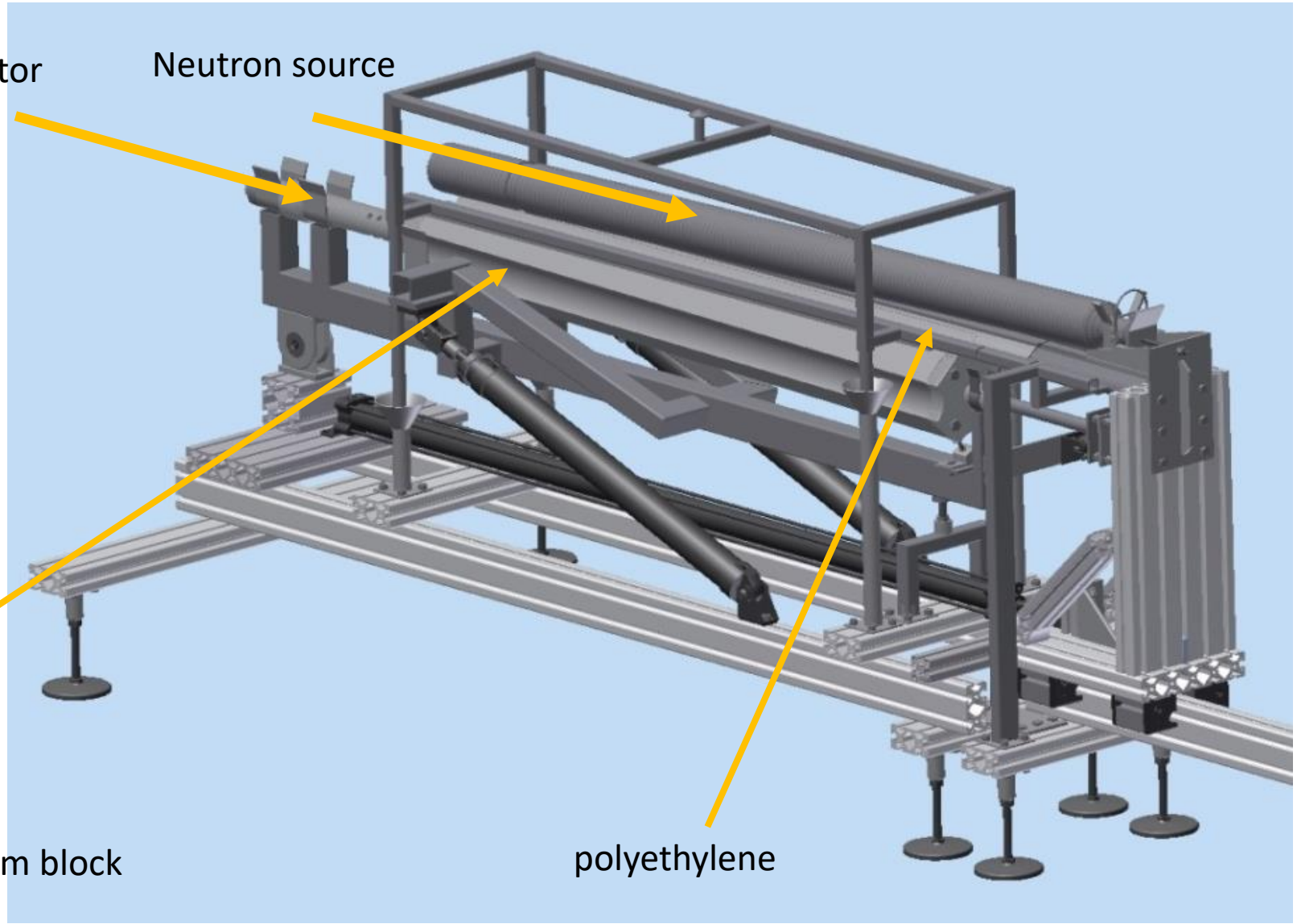


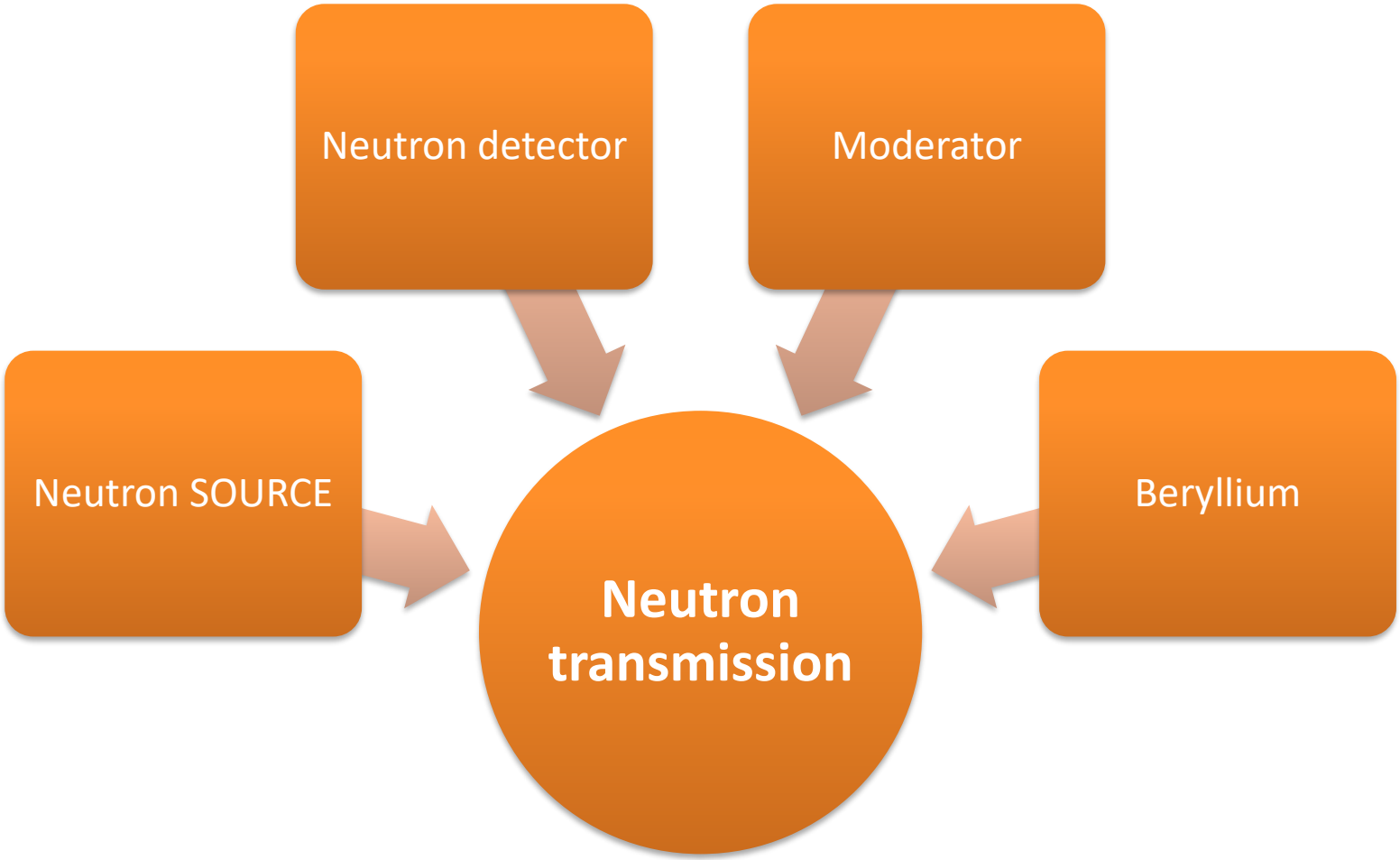




$$\frac{I_1}{I_2} = f(\Sigma_{poisons})$$

***Monte – Carlo transport calculations***

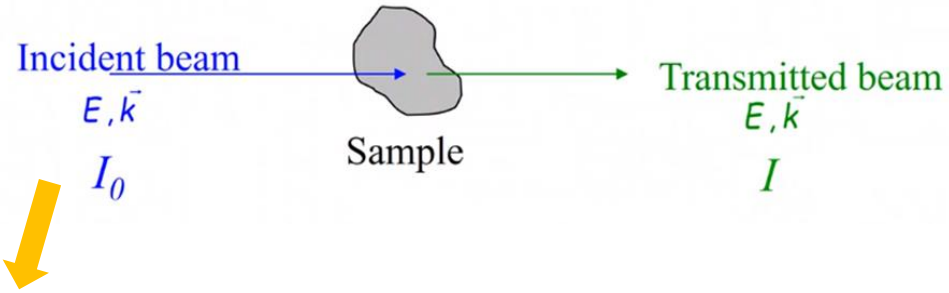
# Experiment – transmission method

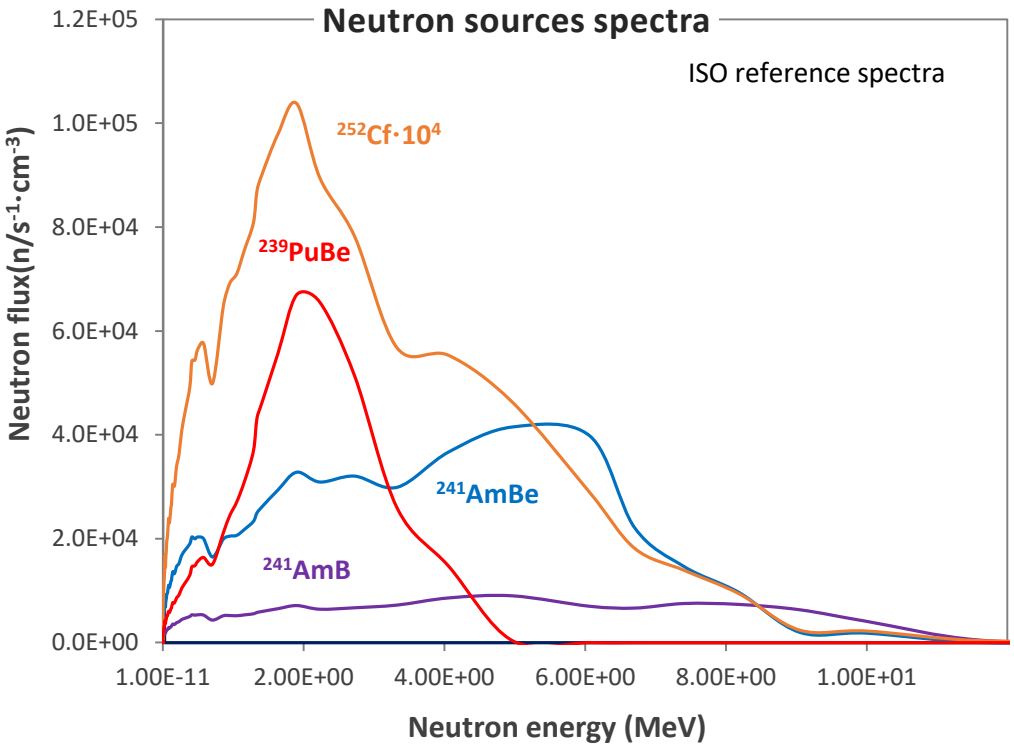


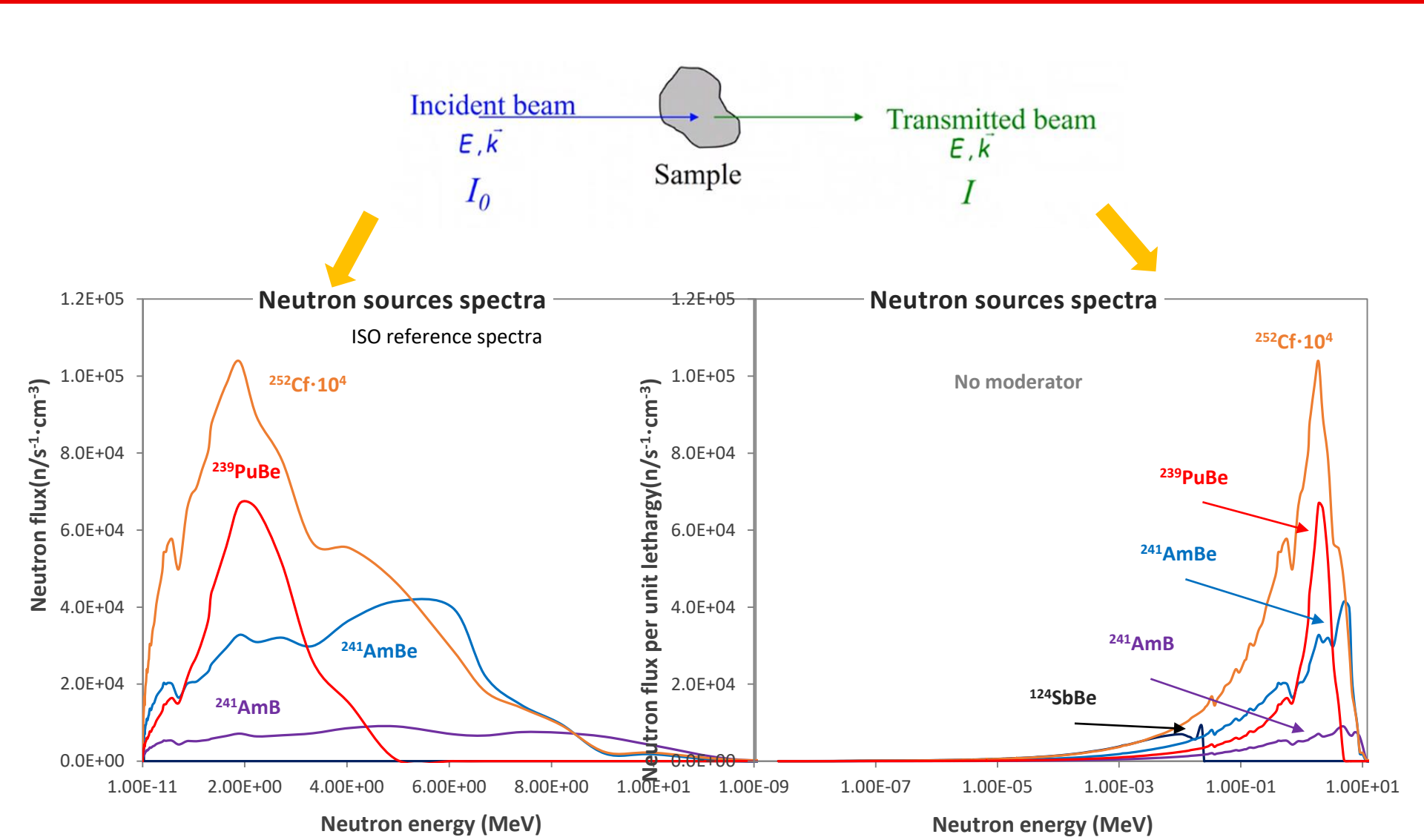

Neutron detector
Moderator
Neutron SOURCE
Beryllium
Neutron transmission

- Poisoning effect in MTRs
- Experimental setup
- Sensitivity analysis
  - Neutron source
  - Moderator
  - Detector
- Conclusion

- PuBe ($^{239}$Pu/ $^{238}$Pu)
- AmBe ($^{241}$Am)
- AmB($^{241}$Am)
- SbBe ($^{124}$Sb)
- $^{252}$Cf




Incident beam
$E, \vec{k}$
$I_0$
Sample
Transmitted beam
$E, \vec{k}$
$I$
Neutron sources spectra
ISO reference spectra
$^{252}Cf \cdot 10^4$
$^{239}PuBe$
$^{241}AmBe$
$^{241}AmB$
Neutron flux(n/s$^{-1}$·cm$^{-3}$)
Neutron energy (MeV)
Neutron sources spectra
No moderator
$^{252}Cf \cdot 10^4$
$^{239}PuBe$
$^{241}AmBe$
$^{241}AmB$
$^{124}SbBe$
Neutron flux per unit lethargy(n/s$^{-1}$·cm$^{-3}$)
Neutron energy (MeV)

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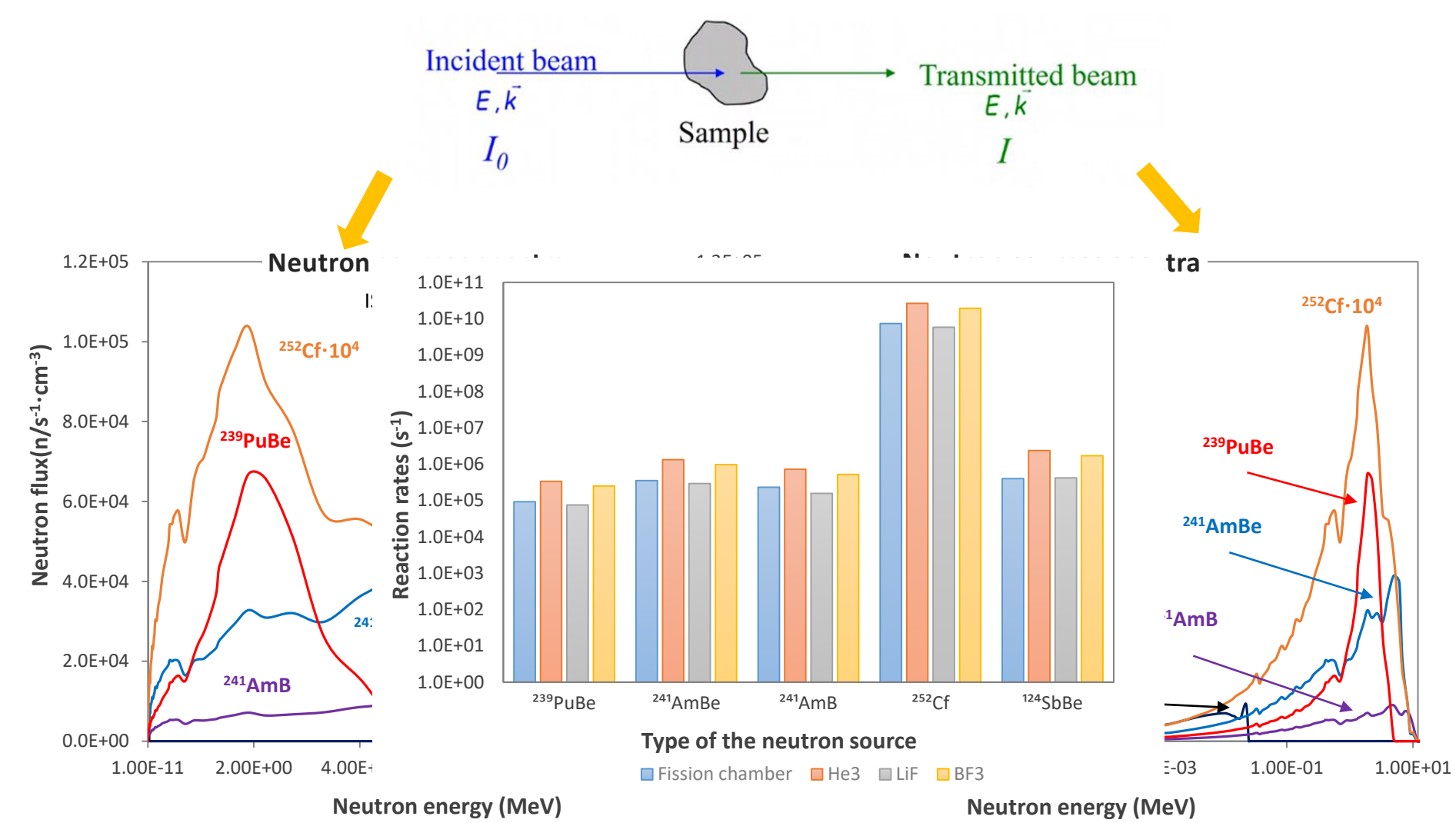
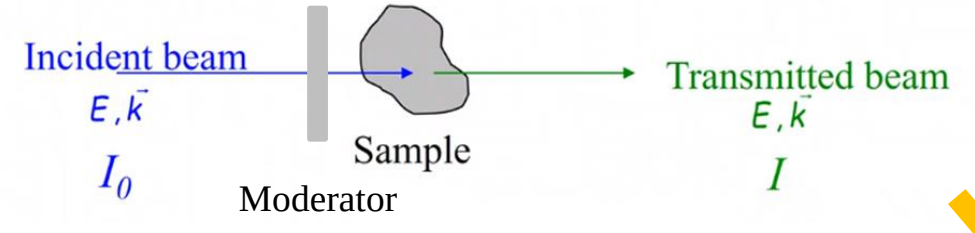
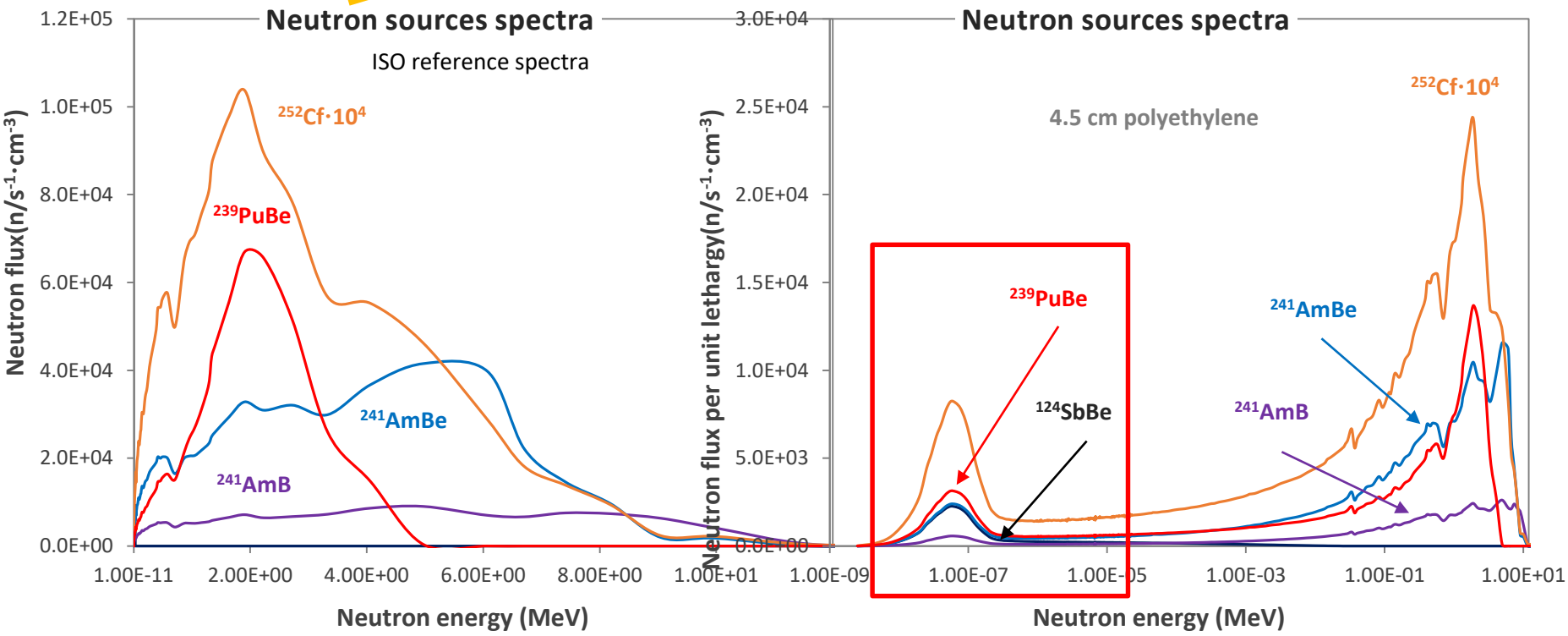



Incident beam
$E, \vec{k}$
$I_0$
Sample
Moderator
Transmitted beam
$E, \vec{k}$
$I$


Neutron sources spectra
ISO reference spectra
Neutron flux(n/s-1·cm-3)
252Cf·10^4
239PuBe
241AmBe
241AmB
1.2E+05
1.0E+05
8.0E+04
6.0E+04
4.0E+04
2.0E+04
0.0E+00
1.00E-11
2.00E+00
4.00E+00
6.00E+00
8.00E+00
1.00E+01
Neutron energy (MeV)
Neutron sources spectra
4.5 cm polyethylene
Neutron flux per unit lethargy(n/s-1·cm-3)
252Cf·10^4
239PuBe
124SbBe
241AmBe
241AmB
3.0E+04
2.5E+04
2.0E+04
1.5E+04
1.0E+04
5.0E+03
0.0E+00
1.00E-09
1.00E-07
1.00E-03
1.00E-01
1.00E+01
Neutron energy (MeV)

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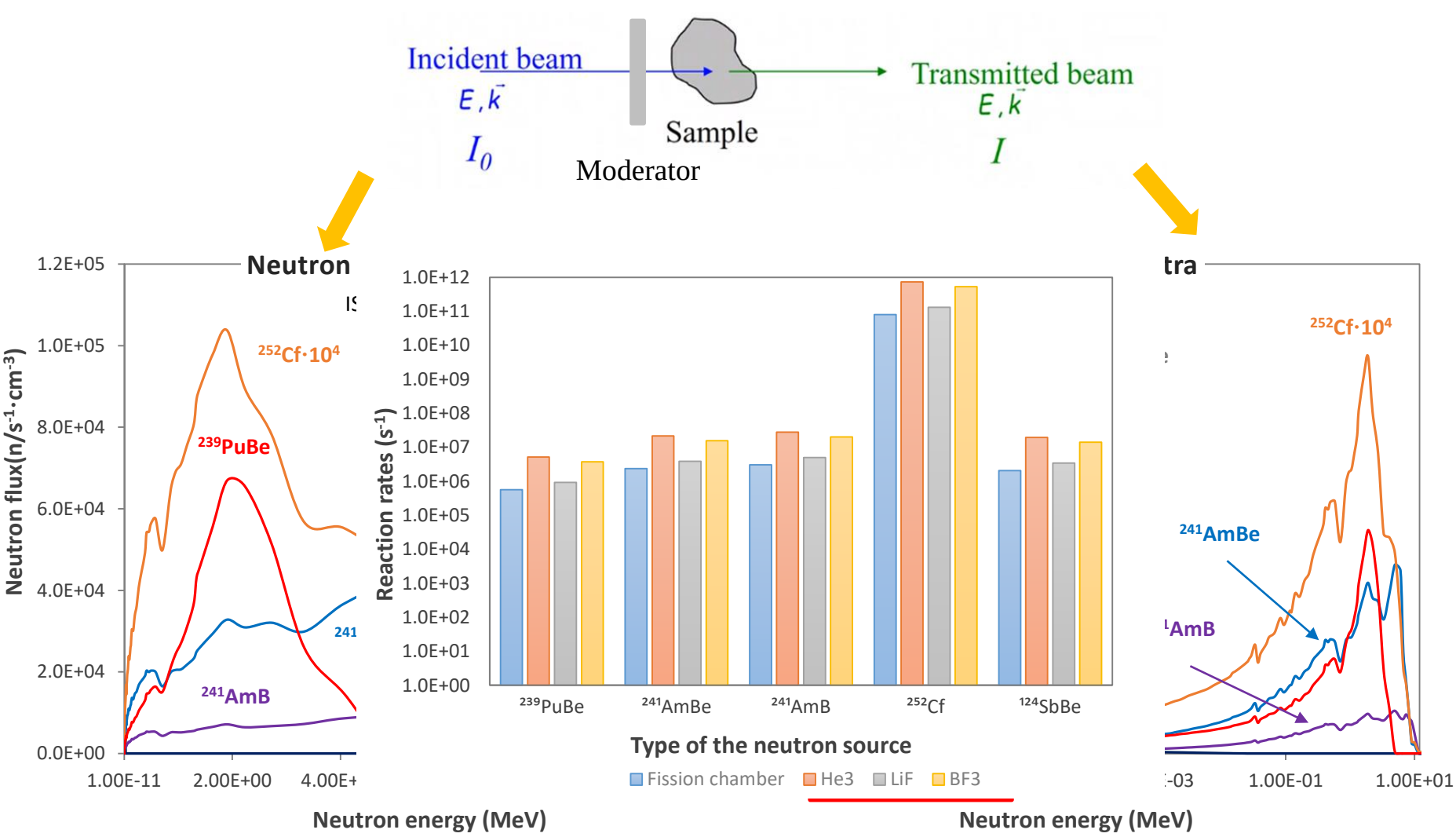

- Poisoning effect in MTRs
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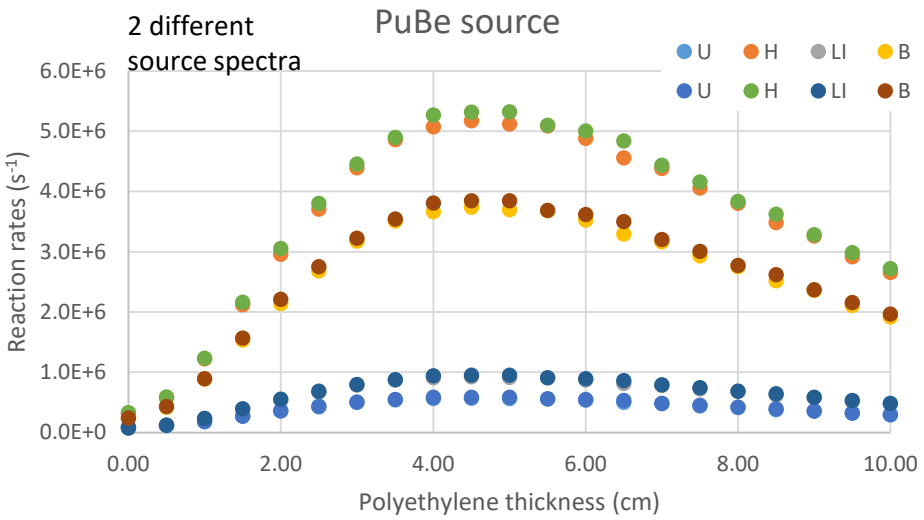
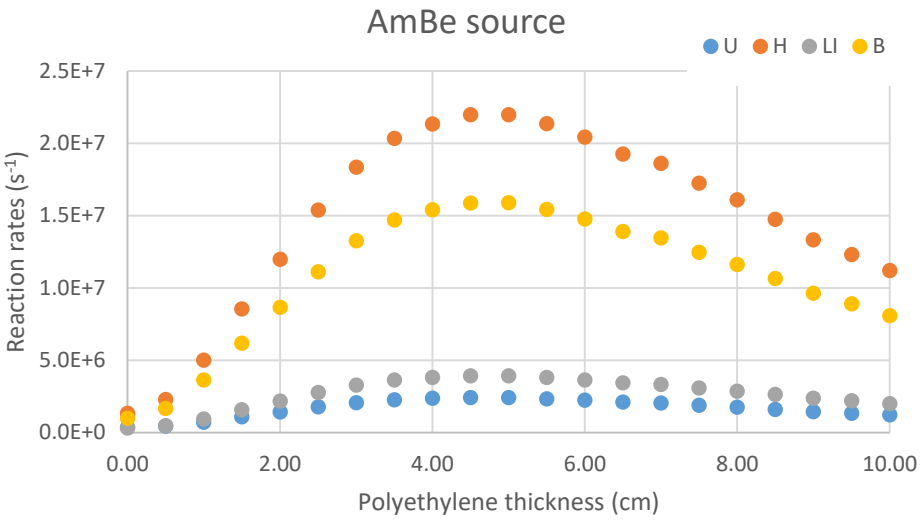
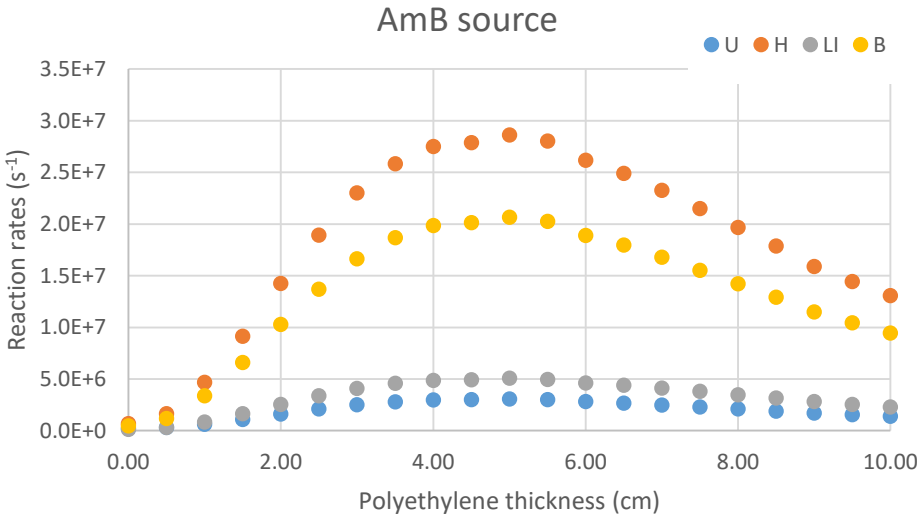
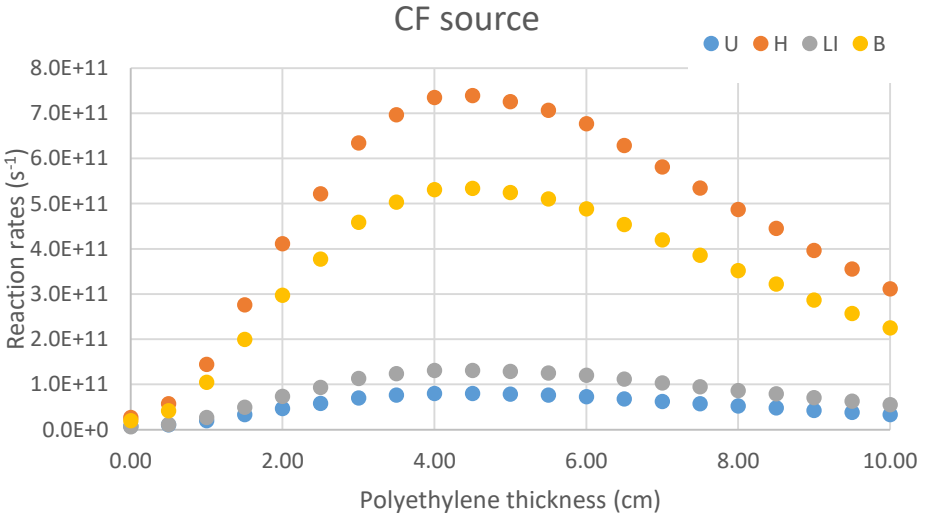
# SENSITIVITY ANALYSIS OF AN ADVANCED MEASUREMENT METHOD FOR THERMAL NEUTRONS ABSORBERS DETECTION IN IRRADIATED BERYLLIUM

2 different source spectra



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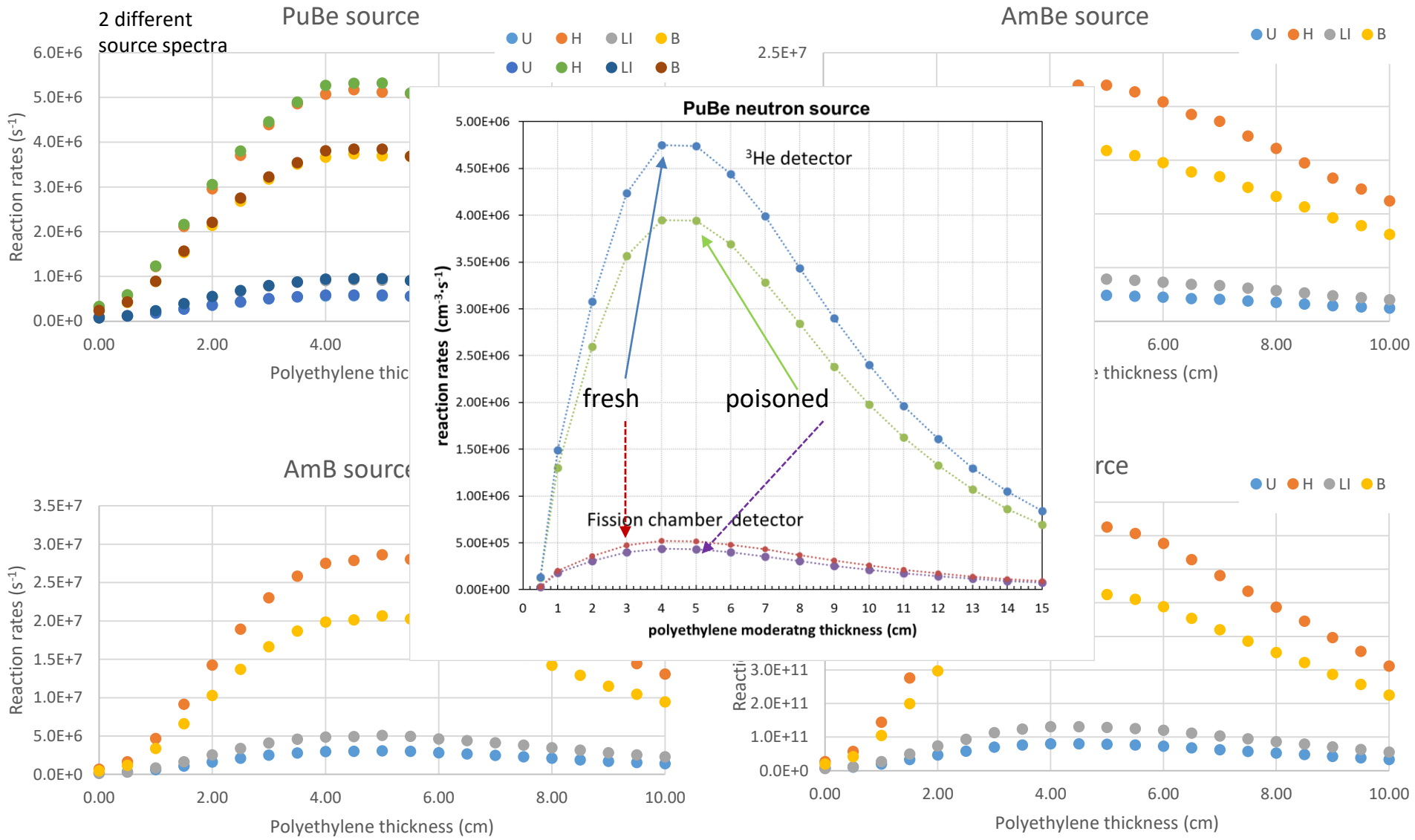

# Neutron detector and source choice

**γ SOURCES IN THE MEASUREMENT SET**

| | |
|---|---|
| (n,γ) on $^{9}$Be ~2MeV | ~6.81MeV |
| γ activation of irradiated beryllium | ~$10^{6}$ Bq |
| γ from the neutron source | SbBe ~2.7 $10^{-3}$ Gy/hr<br>PuBe ~2.7 $10^{-8}$ Gy/hr |
| γ from radiative capture polyethylene | ~2.2MeV |
| (γ,n) reactions induced by the above | 1.67MeV |

PuBe + fission chamber

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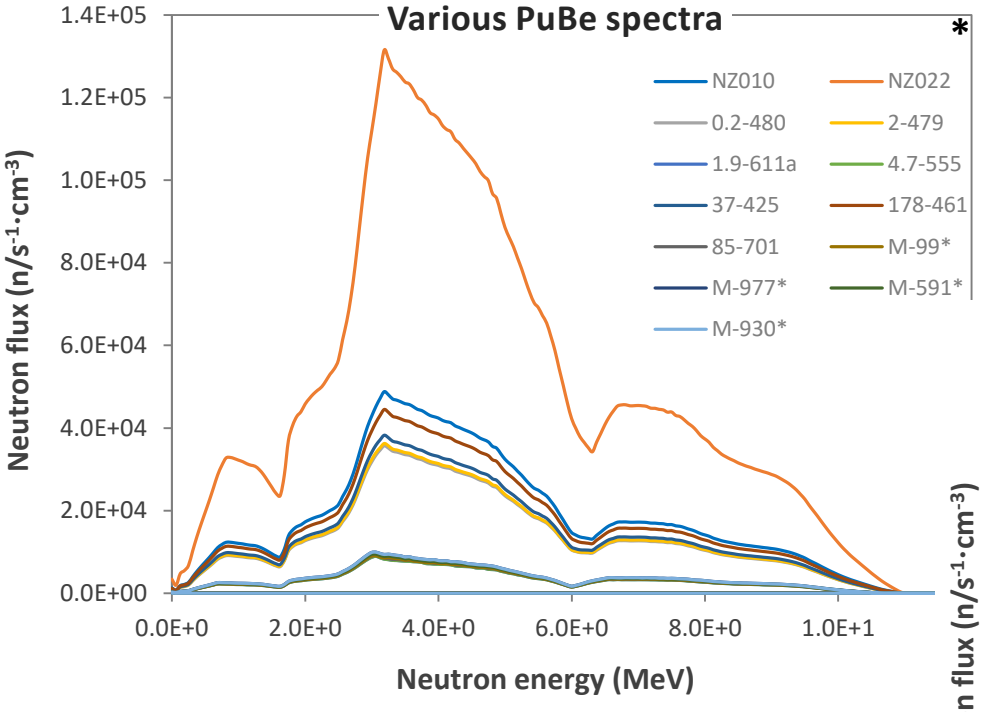
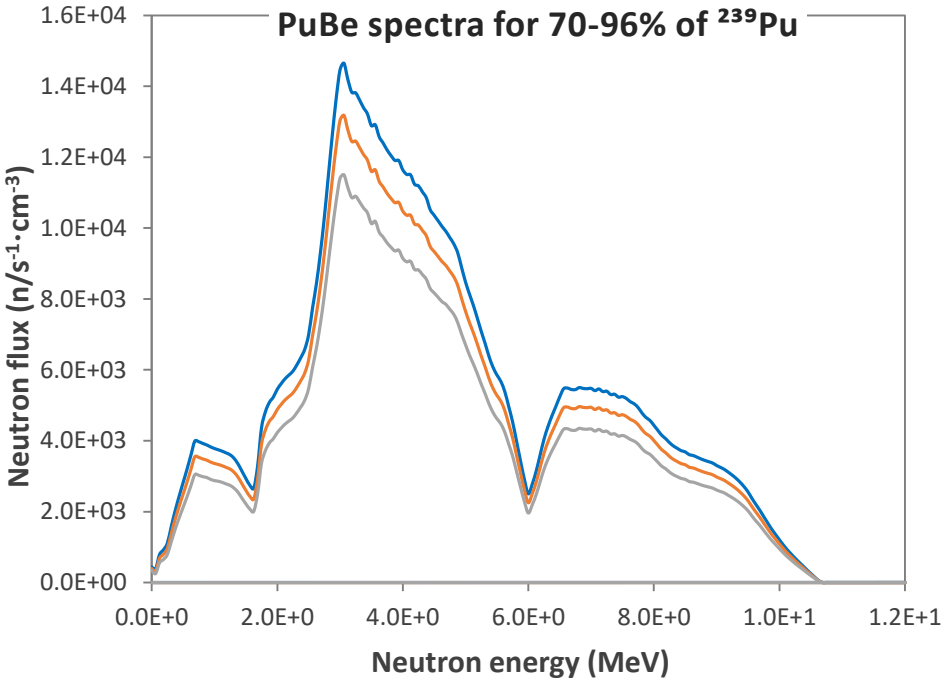



Thanks to **BOULAND Olivier**
code **iSourceC**

DES/IRESNE/DER/SPRC/Physics Studies Laboratory




* Based on PuBe neutron source data from:

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2. Lockhart, M.L. & McMath, G.E.. (2017). Verification of Plutonium Content in PuBe Sources Using MCNP® 6.2.0 Beta with TENDL 2012 Libraries. Physics Procedia. 90. 305-312. 10.1016/j.phpro.2017.09.016.

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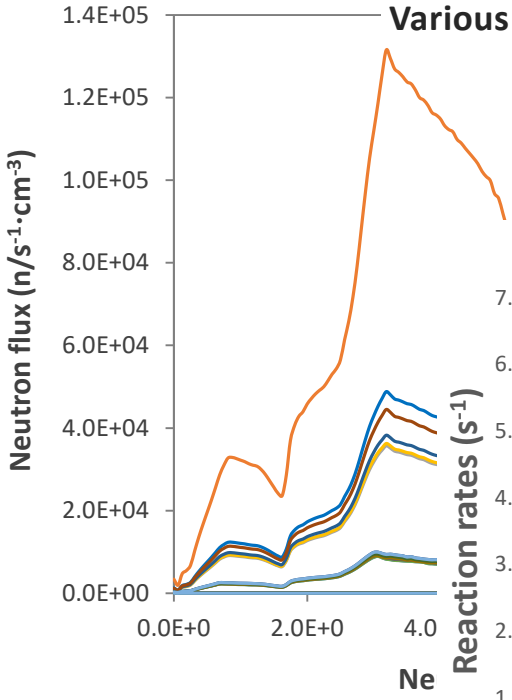


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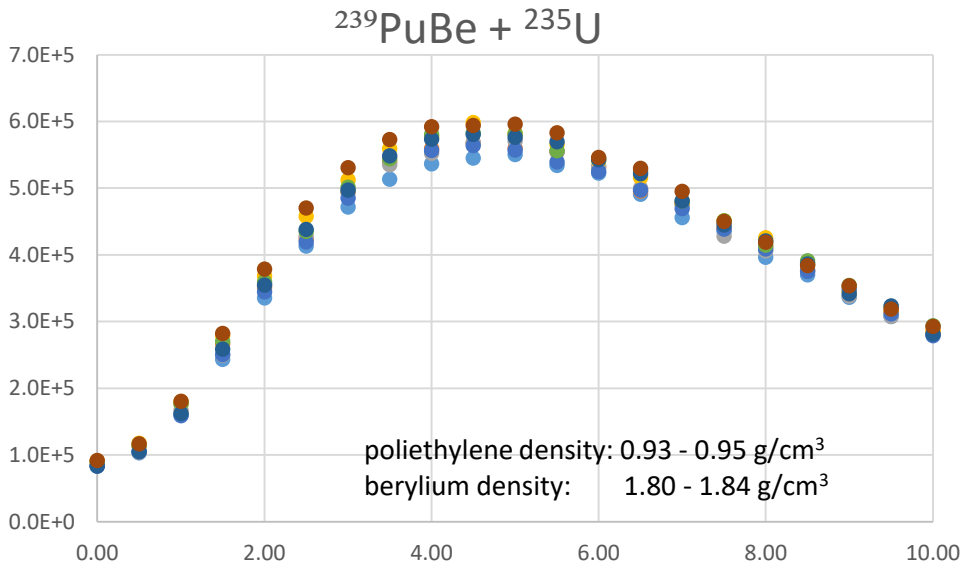


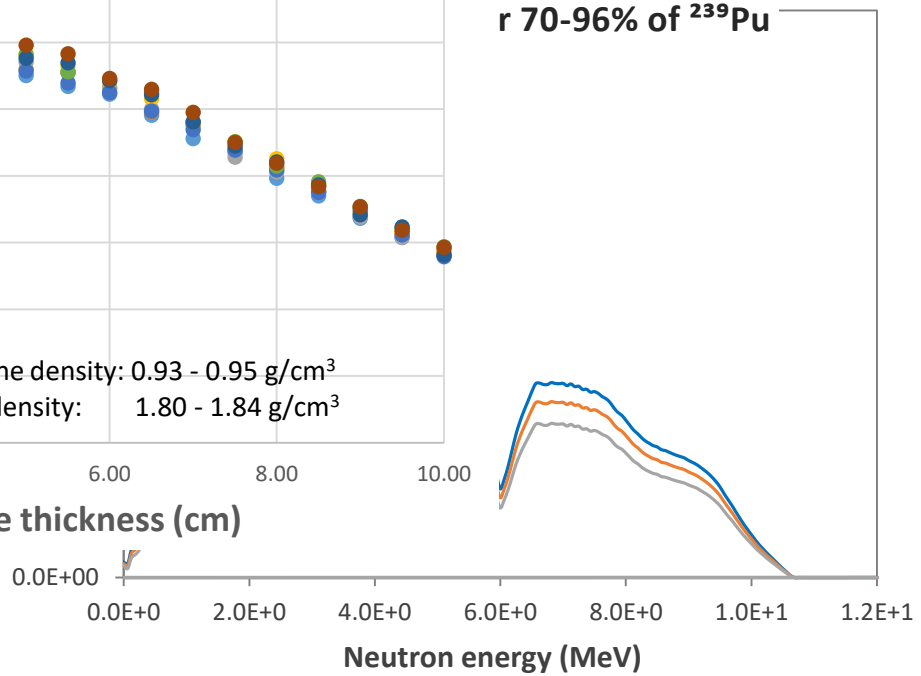


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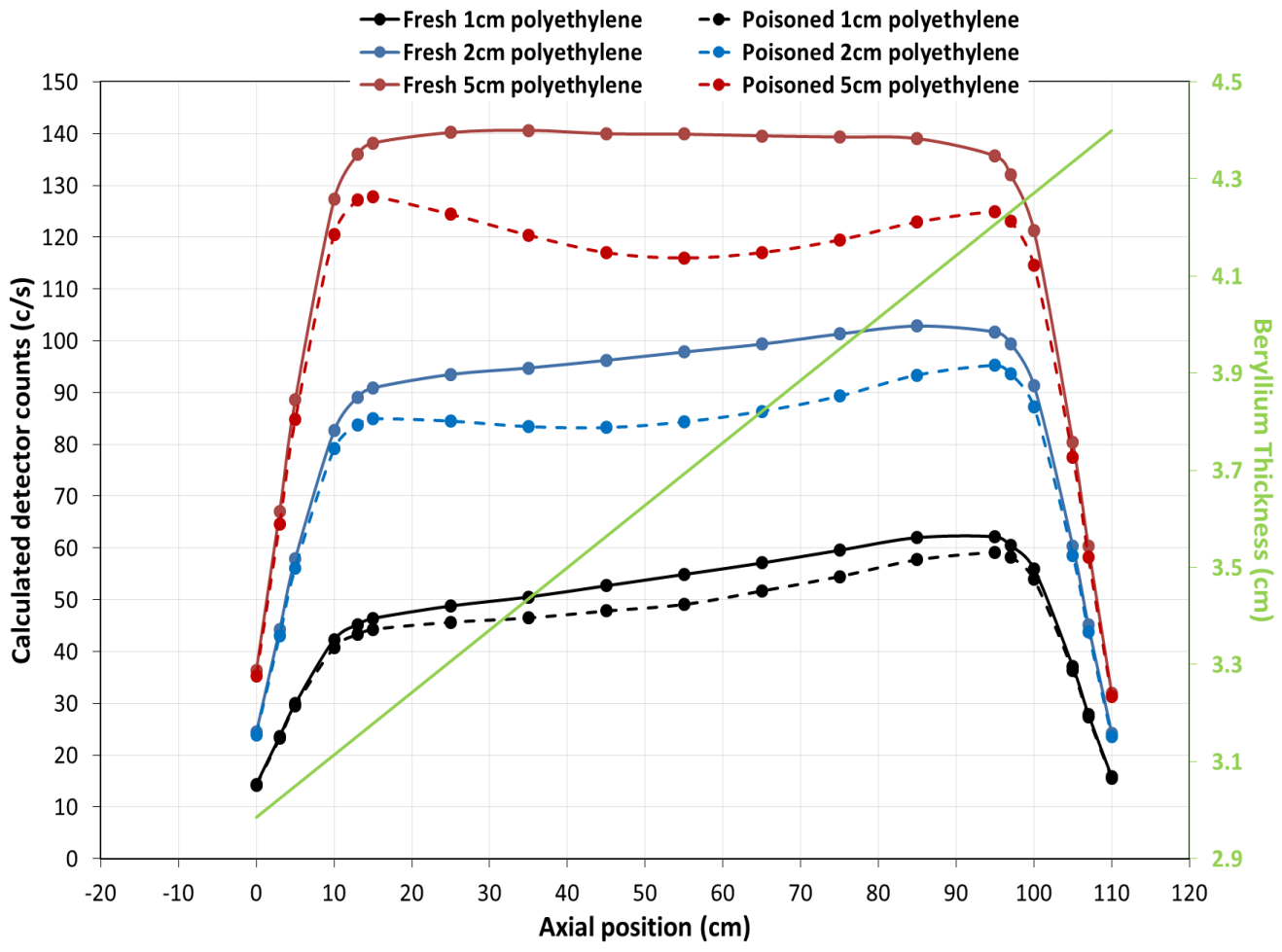
# $^{239}$PuBe + $^{235}$U Fission chamber

SERPENT2
JEFF3.1



# Conclusions

- The chosen configuration of the neutron source-moderator-detector has been tested experimentally
- We obtained good signal resolution
- We still need to verify the beryllium activation and total gammas in the system
- And to perform more measurements

ANY QUESTIONS?

THANK YOU!