The Surrogate Reaction Method Applied to ^{240}Pu

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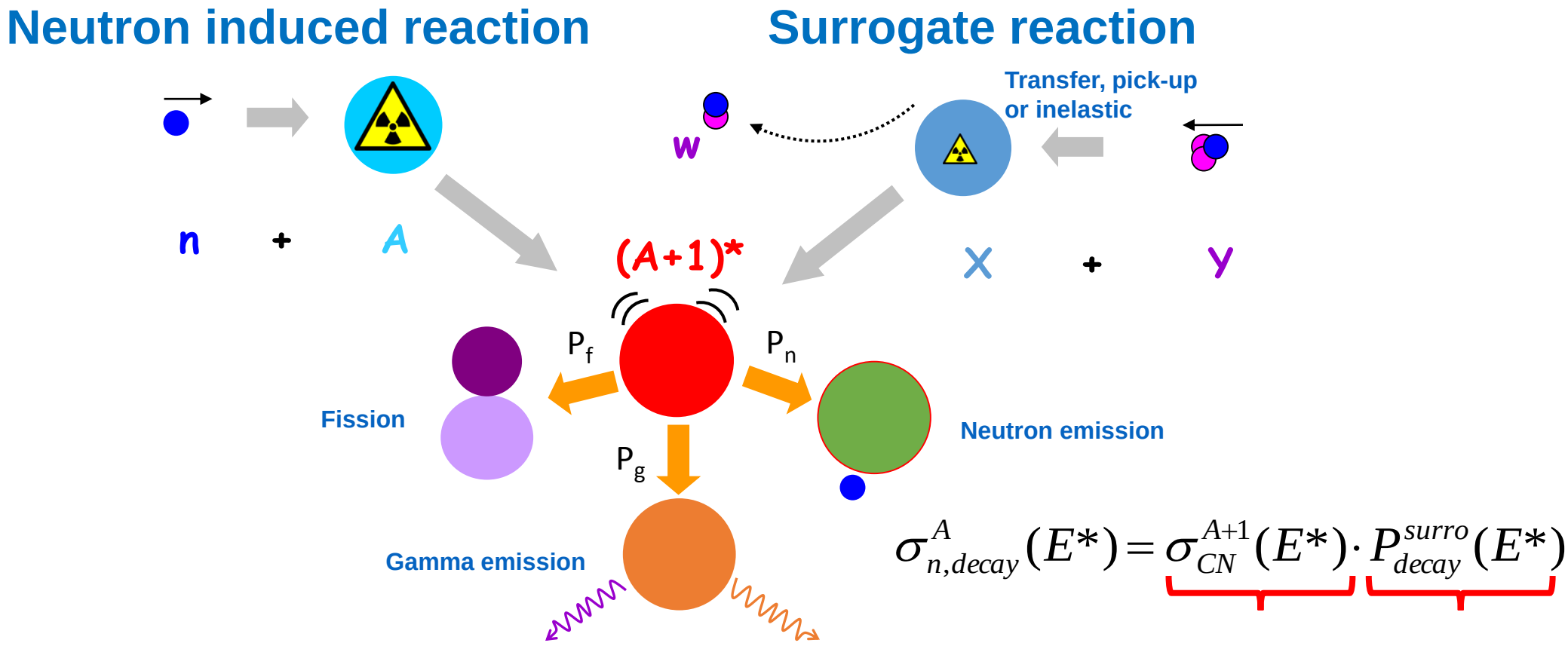
Context

- There is a need of neutron induced cross sections of short-lived nuclei (astrophysics and nuclear reactor physics).
- These are difficult to measure due to the high radioactivity of the nuclei to be studied.
- Alternative methods to the direct measurement have to be investigated.

The Surrogate Reaction Method

Cramer and Britt (Los Alamos 1970)

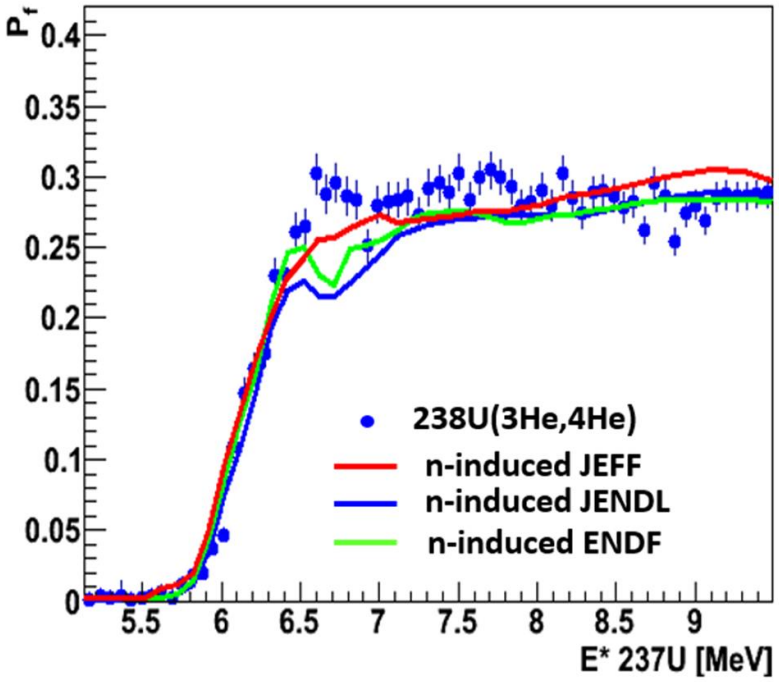


$$\sigma^{A}_{n,decay}(E^*) = \underbrace{\sigma^{A+1}_{CN}(E^*)}_{\text{Theory (Opt. Mod.)}} \cdot \underbrace{P^{surro}_{decay}(E^*)}_{\text{Experiment}}$$

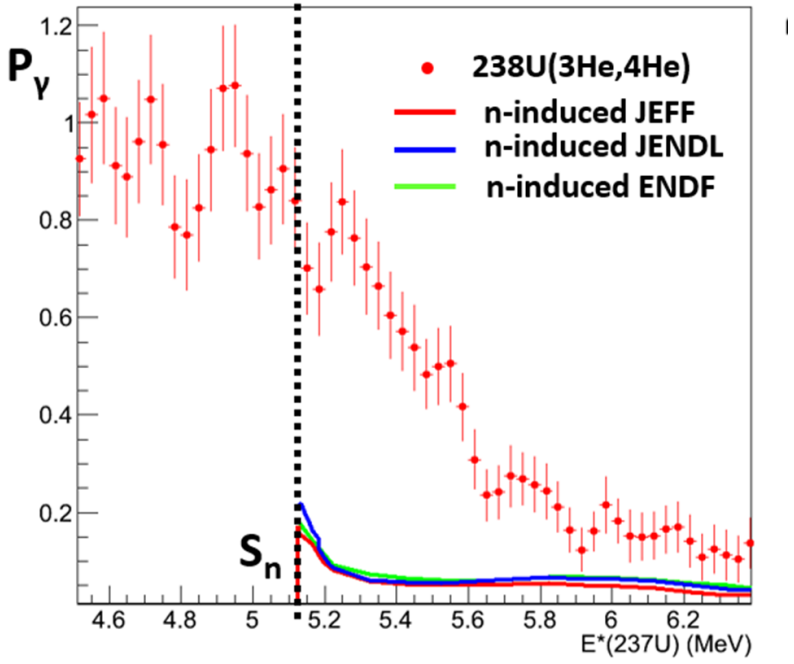
Previous Results: $^{238}U(^{3}He,^{4}He)^{237}U \leftrightarrow n+^{236}U$

P. Marini et al. (to be published)

Fission probability



Gamma decay probability



Why such differences? In general fission is less sensitive to the entrance channel.

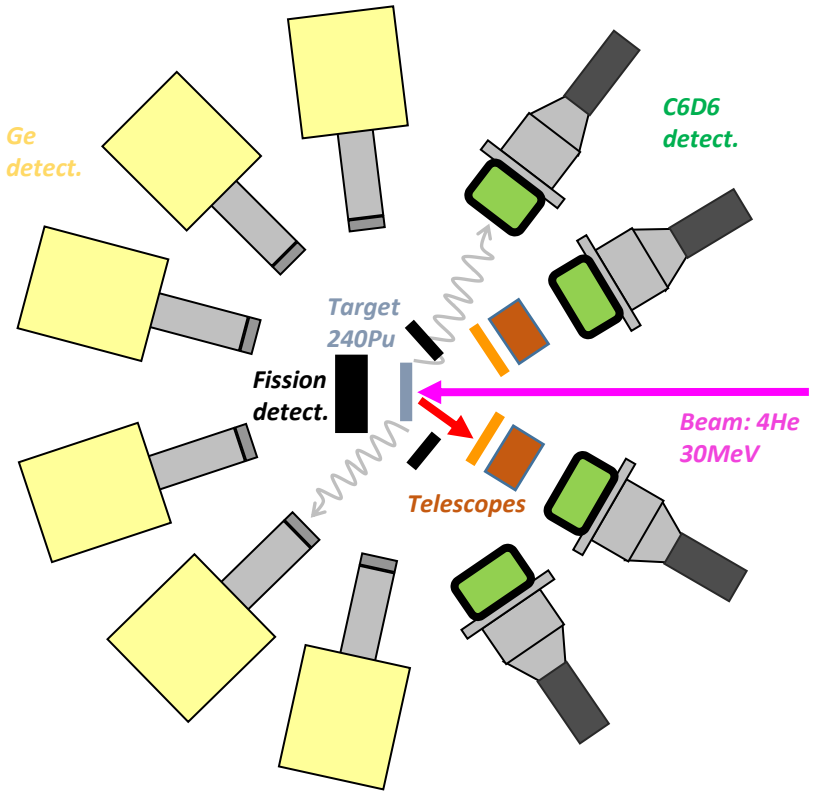
Why ^{240}Pu?

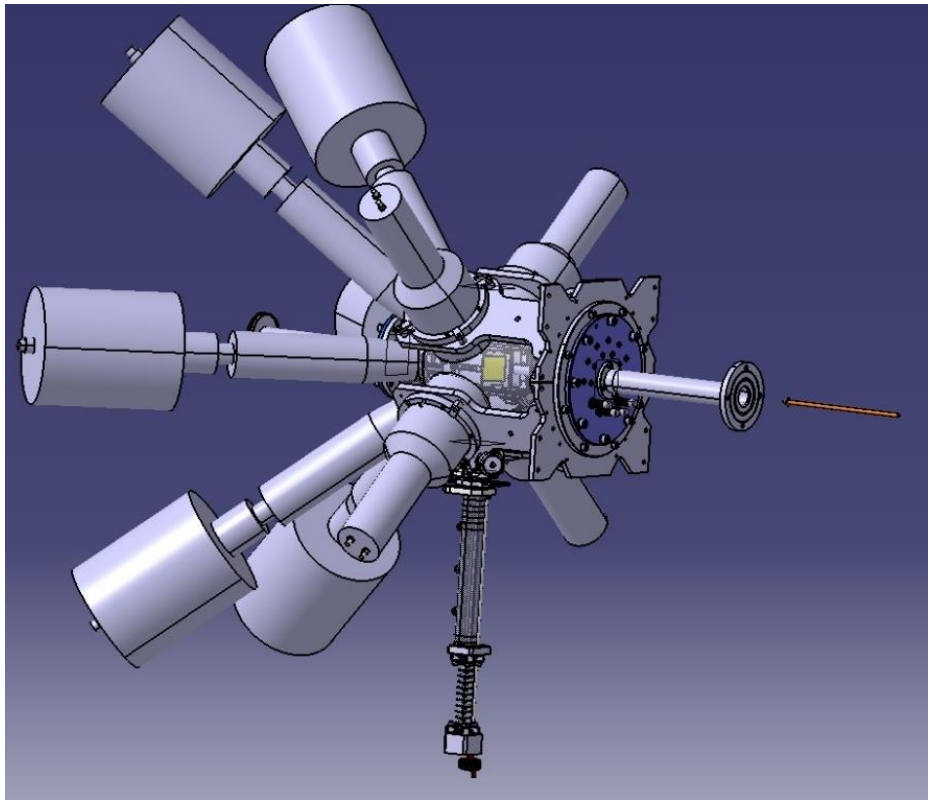
- These behaviour differences between gamma decay and fission probabilities are not yet understood.

- Well known equivalent neutron induced reaction n+^{239}Pu.

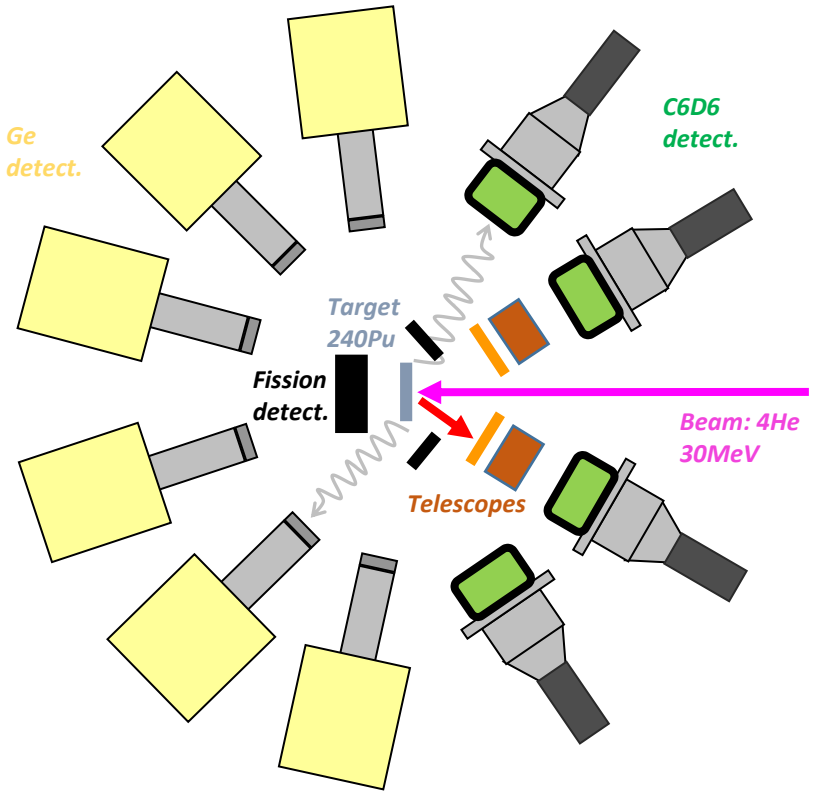
- It is a fissile even-even nucleus, thus a lower level density than in odd nuclei near to the fission barrier is expected. Previously just odd nuclei were studied by the group.

The experiment: $^{240}Pu(^{4}He,^{4}He') \leftrightarrow n+^{239}Pu$





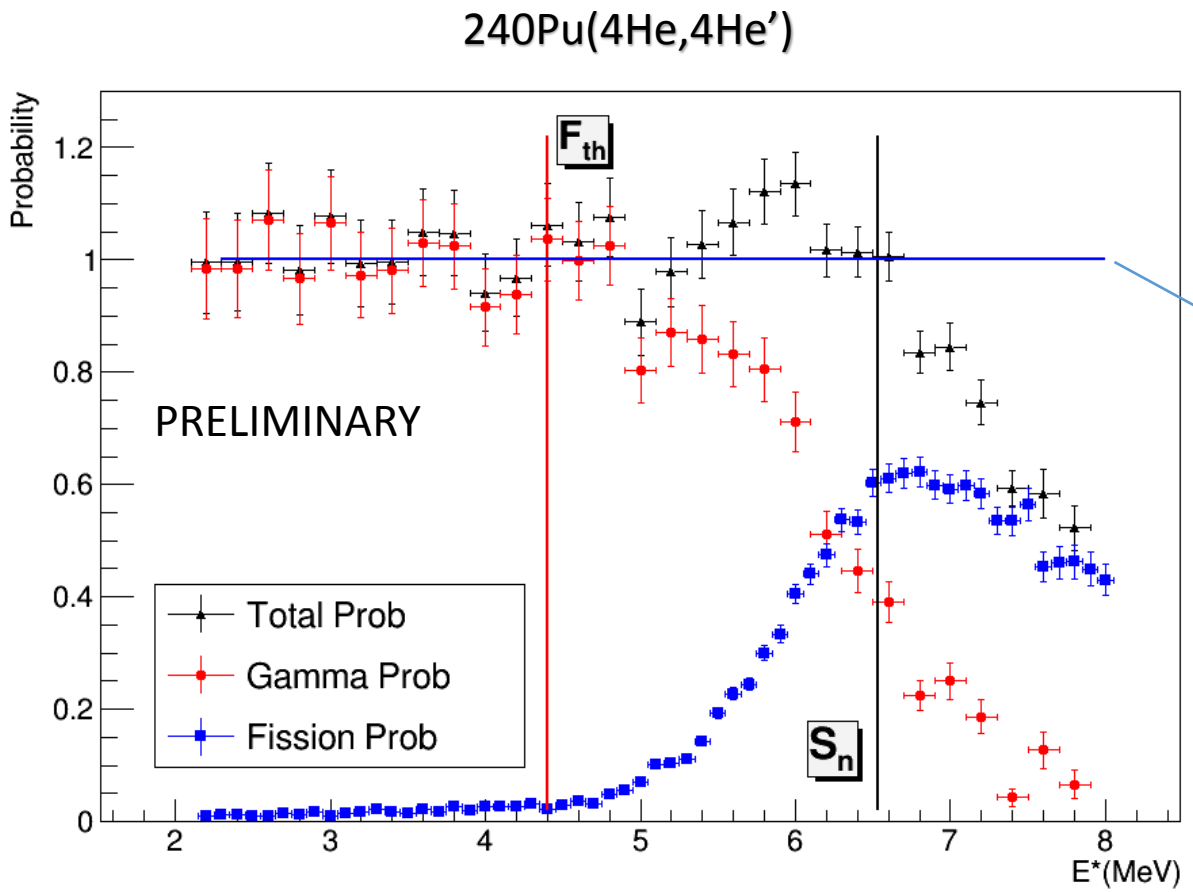
The experiment: ^{240}Pu(^{4}He,^{4}He') $\leftrightarrow$ n+^{239}Pu



$$P_{\chi}^{surro}(E^*) = \frac{N_{c_\chi}(E^*)}{N_s(E^*) \cdot \varepsilon_\chi(E^*)}$$

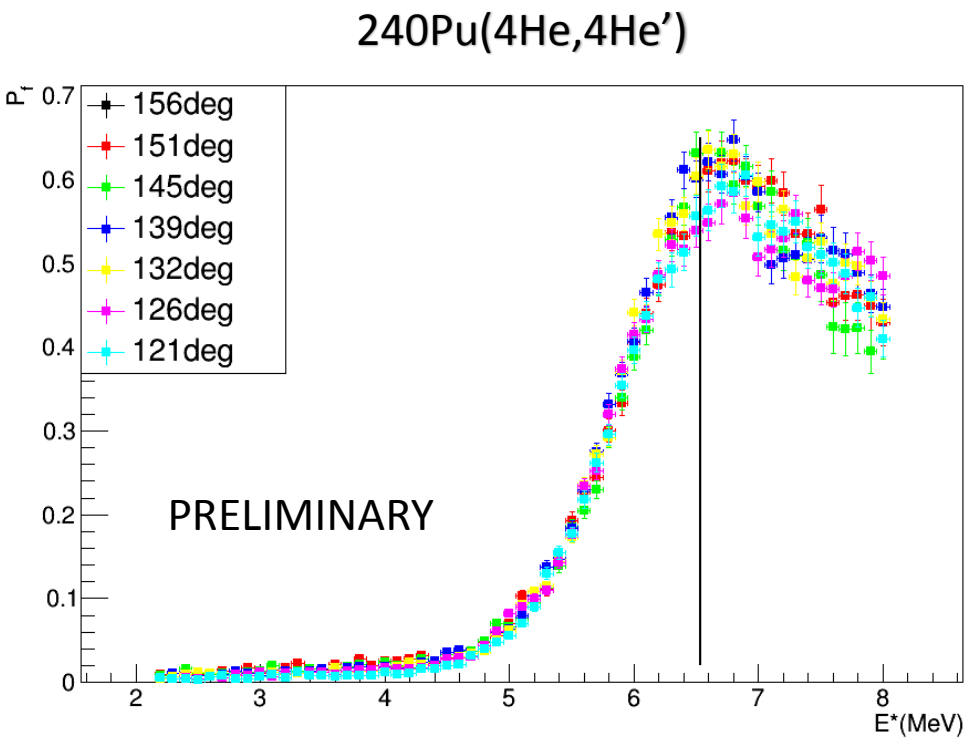
- Simultaneous measurement of fission and gamma decay probabilities.
- Challenging to substract gammas coming from fission fragments.

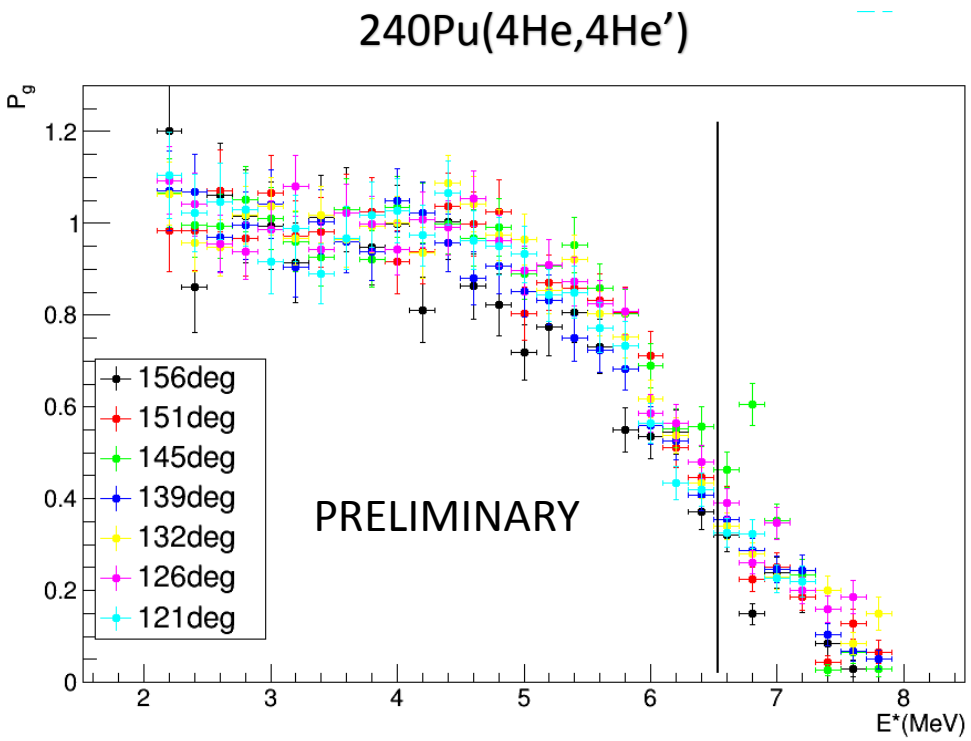
Preliminary Results: Validation of the method



The fact that the total decay probability below Sn is equal to 1 validates the method!

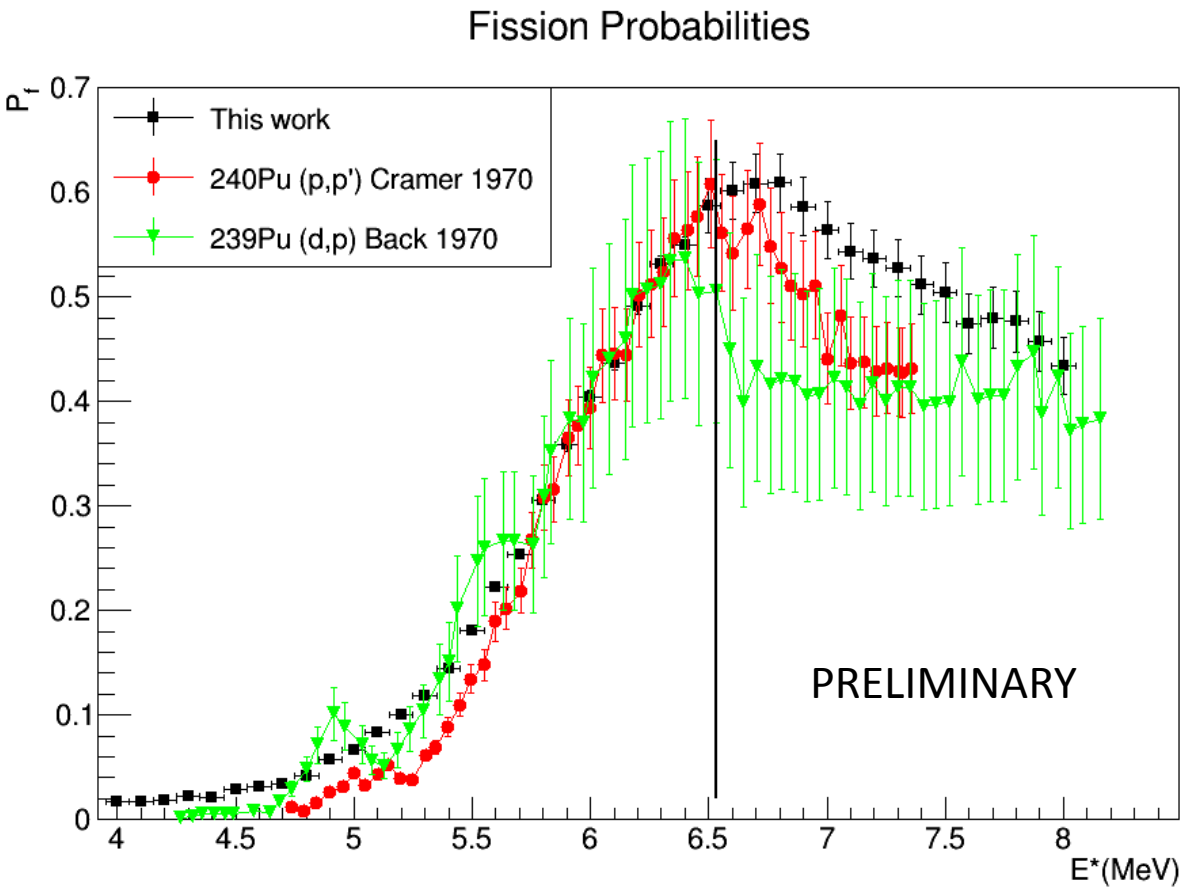
Preliminary Results: Angle Comparison





No dependence on the detection angle of the scattered particles is observed.

Preliminary Results: Comparison with Previous Experiments

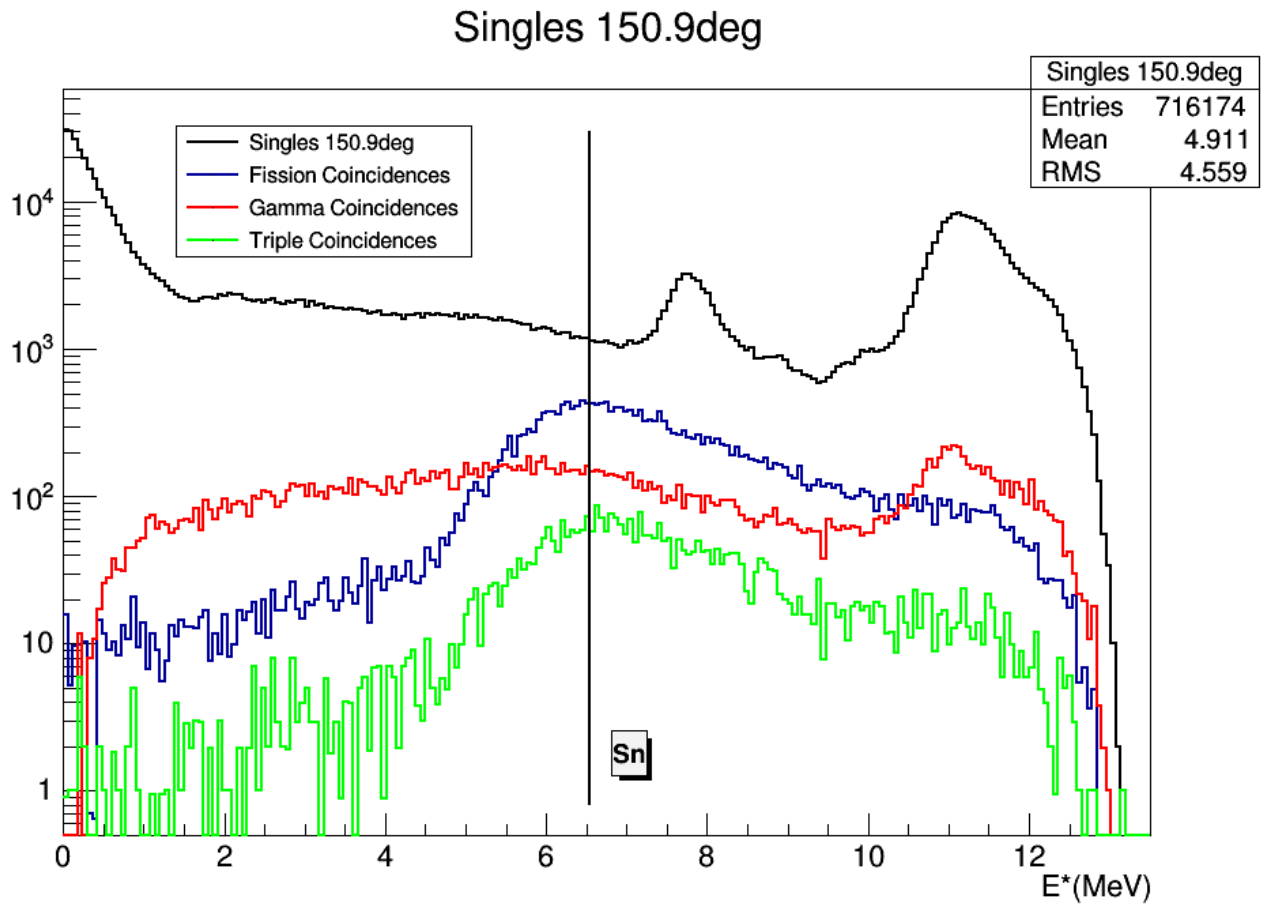


Previous experiments suffered from significant background due to target contaminants.

Conclusions and Perspectives

- First simultaneous measurement of P_f and P_g for ^{240}Pu(4He,4He').
- No angular dependence observed.
- Fission probabilities are in good agreement with other experiments under Sn but systematically higher than them over this energy.
- Perspectives:
  - Comparison with neutron induced data.
  - Use the statistical model for the interpretation of the results.
  - Study of the ^{240}Pu(^{3}He,^{3}He') and ^{240}Pu(^{3}He,^{4}He) reactions measured in the same experiment.

Singles and Coincidences



Efficiency Obtention

Fission

- Fission fragment angular distribution, simulation.
- Use of an isotropic source of 252Cf to obtain the efficiency.

Gamma

- EXEM method (NIMPR A 826 (2016) 60-64).
- Neutrons separeted using a PSD system.
- Gamma energy thresholds.

EXEM Method

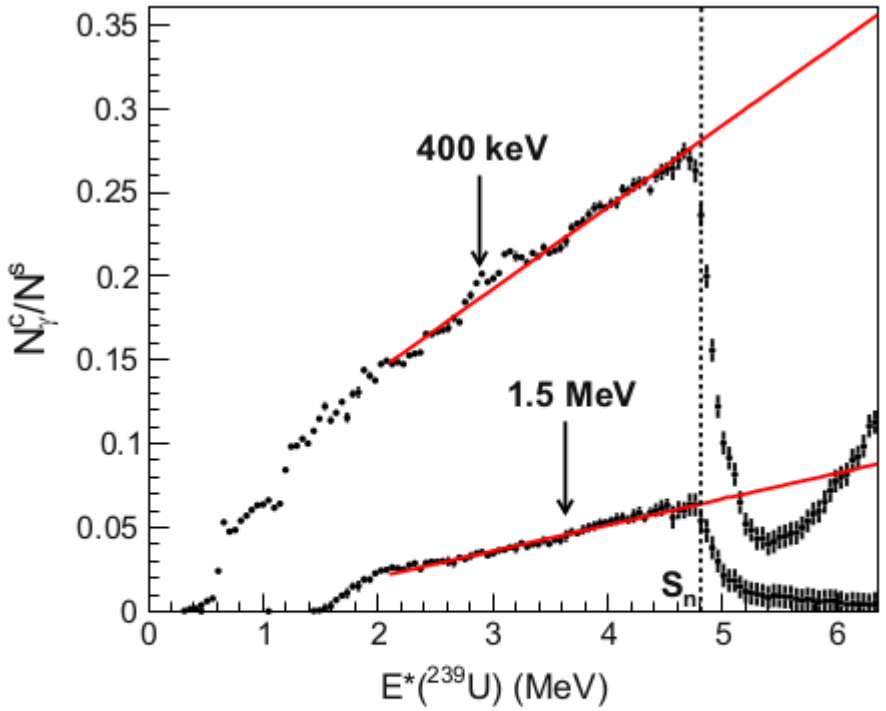


Fig. 2. Ratio between the number of gamma-ejectile coincidences and the total number of detected ejectiles as a function of the excitation energy of $^{239}U^*$ for two gamma-ray energy thresholds of 400 keV and 1.5 MeV. The ejectiles were detected at 126°. The vertical dotted line indicates the neutron separation energy of ^{239}U and the red solid lines are linear fits to the data in the E^* interval [2 MeV; S_n]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)