Neutron emission from spontaneous fission of heavy elements at FLNR

Adam Broniš, Adam Sitarčík, Pavel Jíška

Comenius University Bratislava, ČVUT Prague

Supervisor: Alexander Svirikhin

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What are we studying?

Spontaneous fission of heavy elements

How the data were obtained?

Experimental background - SHELLS velocity separator + $^{3}\mathrm{He}$ neutron detectors

What did we obtained?

Results - Neutron multiplicities

Heavy elements are produced via fusion-evaporation reactions.

Formation

of compound nucleus (CN) from colliding nuclei.

Evaporation of nucleons/α

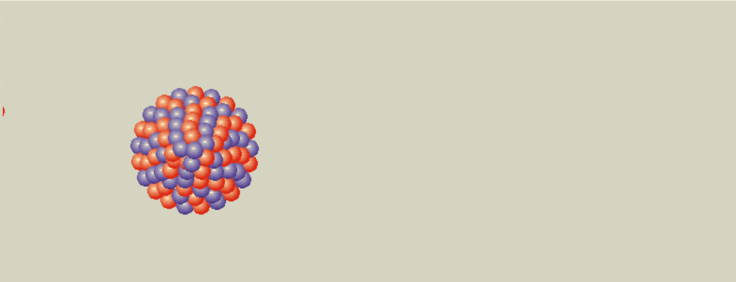
from compound nucleus $\rightarrow$ evaporation residues (ER).

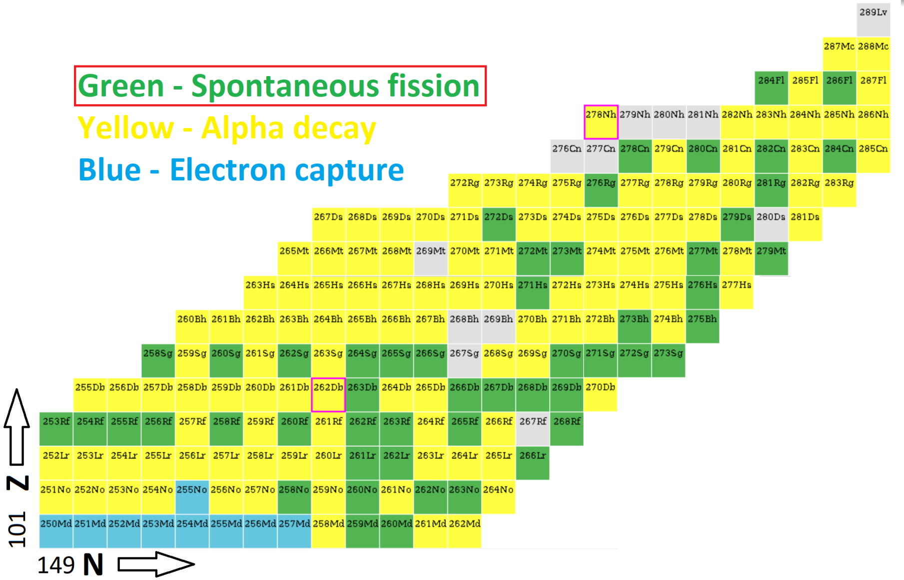
Nucleon-nucleon interactions

lead to thermal equilibrium.

Deexcitation of ERs

Emission of γ rays.





Spontaneous fission - dominant way of decay in many HE!

Spontaneous fission

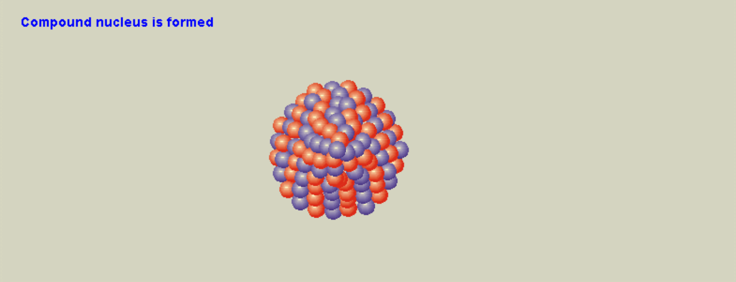
is a radioactive decay in heavy elements when mother nucleus is divided into two lighter fragments. Usually accompanied by the neutron emission.

G. Flerov and Petrzhak

discovered spontaneous fission of uranium in 1940.

Half-life of spontaneous fission

in heavy elements strongly depends on the magic numbers.



Mass distribution.

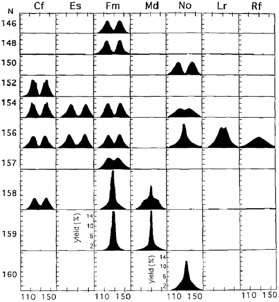
Symetric or asymetric (or both) distributions of fragments massess .

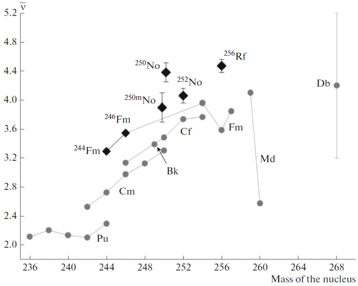
Neutron multiplicities.

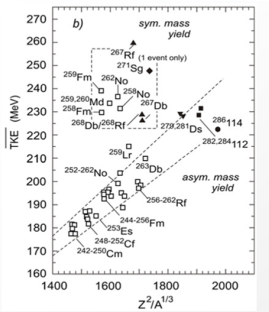
Average number of neutrons emmited in fission.

Total kinetic energies

TKE of fragments - linear trend between TKE and fissility.



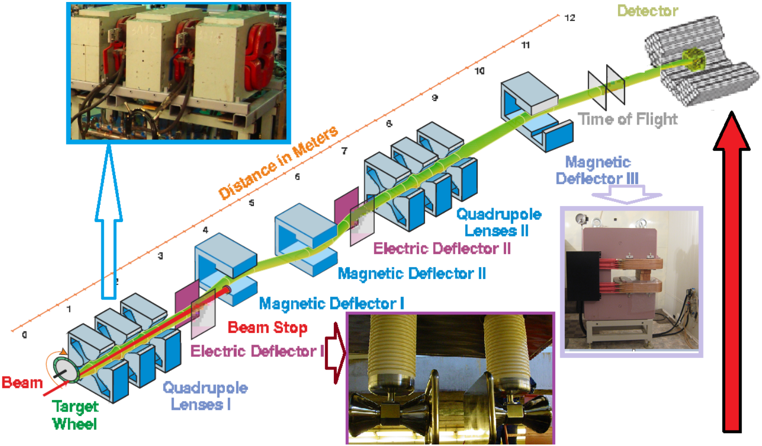




Our goal is to measure neutron multiplicities for $^{248}\mathrm{Cm}$

SHELS - **S**eparator for **H**eavy **EL**ements **S**pectroscopy

different kinematic properties $\Longrightarrow$ separation of projectiles from reaction products. $F_B = F_{el} \Rightarrow -qv_0B = qE \Rightarrow v_0 = E/B$



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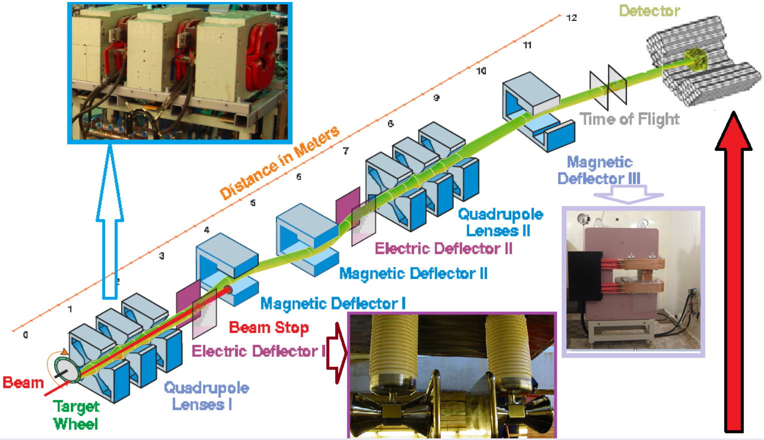
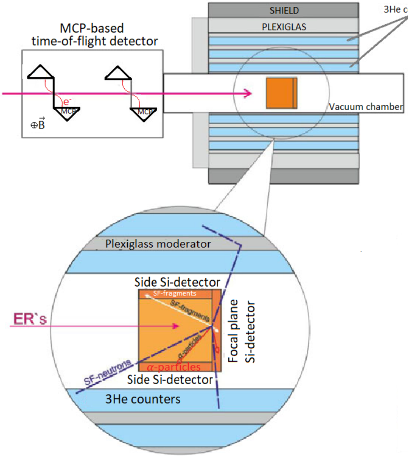
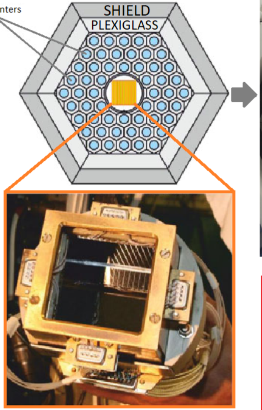


Position sensitive silicon detector (PSSD) inside neutron detector

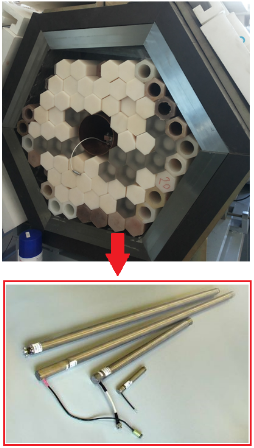
Detector system - 3 main parts:

1. Time of flight - TOF system 2. PSSD detector (fission fragments, α-particles, conversion electrons) 3. $^{3}\mathrm{He}$ detectors





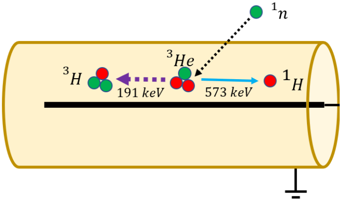
The focal plane Si-detector placed inside the neutron detector



But how to detect (spontaneous fission) neutrons?

Neutron is not charged particle,

thus cannot be registered directly.



However, cross-section 5400 barn

for aforementioned reaction is for thermal neutrons $\approx$ 0.025 eV

Spontaneous fission (1-1.5 MeV) neutrons

has to be thermalised using the plastic moderator.

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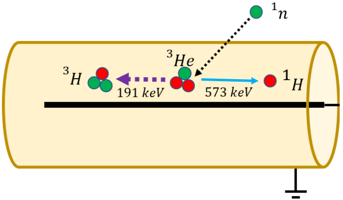

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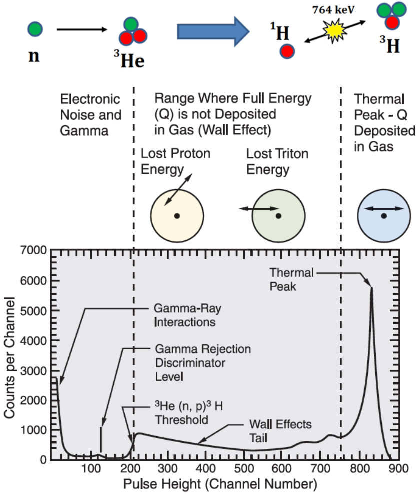
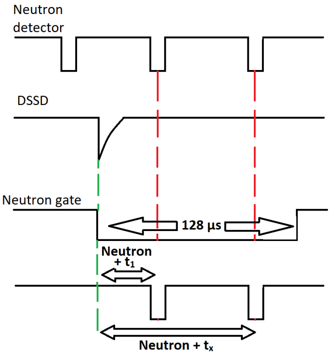
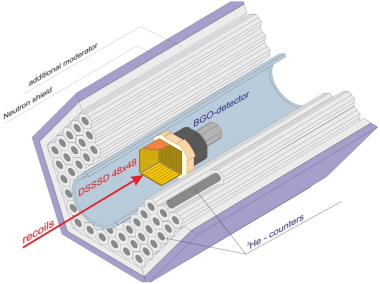


Thermal neutron induced pulse spectrum.

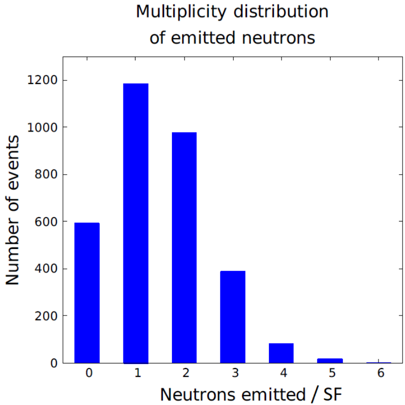
- All neutrons are registered by neutron detectors.
- Fission fragment signal from DSSD is opening 128 μs window.
- Signals from neutrons in DSSD window are saved in form neutron time + time from the beginning of the window.
- Time differences between the beginning of the DSSD window and neutron registration are important to discrimate them from background.

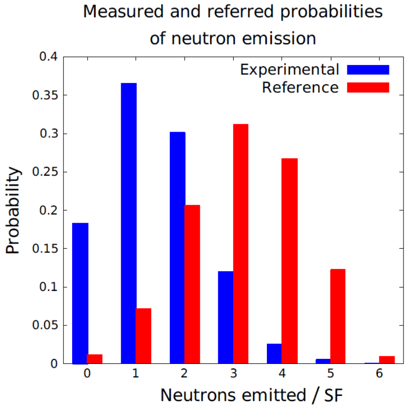




Comparison with reference SF data $^{248}\mathrm{Cm}$ where $\bar{\nu}$ =3.14

Binomial distributions are similar, but experimental distribution is moved to the left.





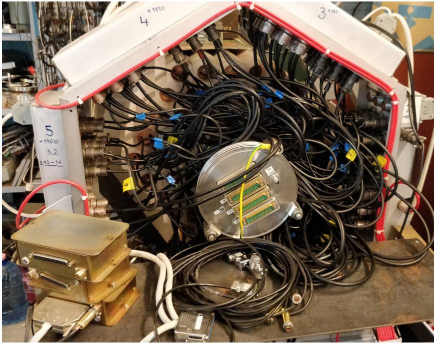
Reason of this shift $\Longrightarrow$ neutron detection efficiency!

$< n >= \bar{\nu} \times Eff = \sum N_i / \sum_{i=0} N_i$ where $< n >$ is average number of neutron detected ($\approx$1.45 / SF). However detection efficiency can be obtained also without the real average multiplicity $\bar{\nu}$ using number of events with i neutron detected and P_n - nth neutron emission probabilities (Sokol et al., NIM A 400, (1997)).

Multiplicity	Events / N_i	Ratio	Value	Efficiency
0	593	N_1/N_2	1.2119	46.94%
1	1184	N_1/N_3	3.0515	45.29%
2	977	N_2/N_3	2.5180	43.77%
3	388	N_3/N_4	4.7317	43.19%
4	82	N_2/N_4	11.9146	43.49%
5	18			
6	1			

Average neutron detector efficiency is 44.53%

- Connection of 54 $^3\mathrm{He}$ detectors not so easy $\Longrightarrow$
- We obtained multiplicity distribution of emmited neutrons.
- Efficiency of neutron detection system $\approx 45 \pm 2$ %.



Thank you for your attention!