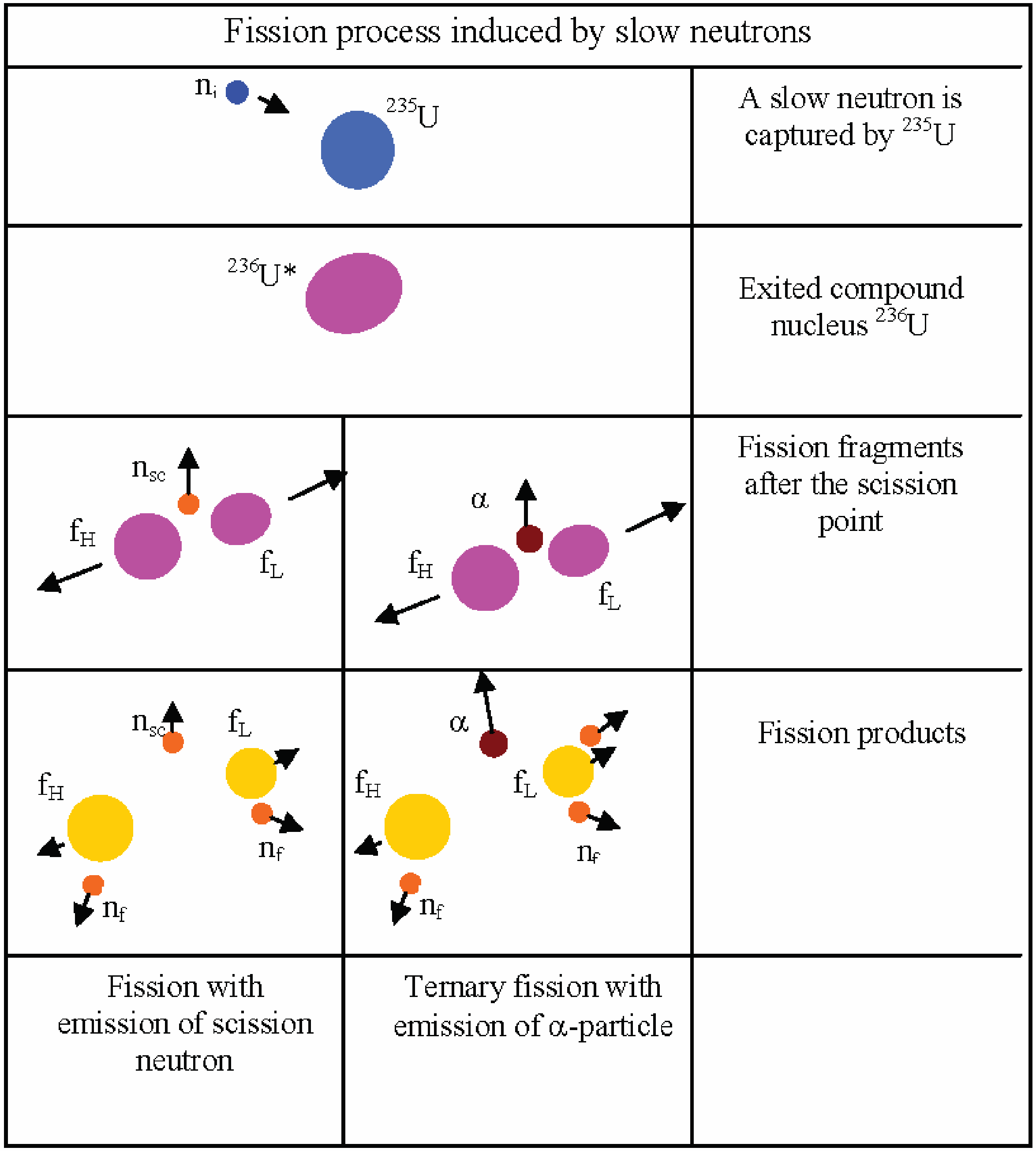
Neutral component of ternary fission

G.V. Danilyan
Alikhanov Institute for Theoretical and Experimental Physics
Moscow, Russia
danilyan@itep.ru

40-th PNPI Winter School
20 - 25 February 2006


Fission process induced by slow neutrons
n_i
^{235}U
A slow neutron is captured by ^{235}U
$^{236}U^*$
Exited compound nucleus ^{236}U
n_{sc}
f_H
f_L
α
f_H
f_L
Fission fragments after the scission point
n_{sc}
f_L
f_H
n_f
n_f
α
f_H
f_L
n_f
n_f
Fission products
Fission with emission of scission neutron
Ternary fission with emission of α-particle

Neutral component of ternary fission

- Introduction
- Short about fission neutrons
- Specific angular correlation as a tool to study fission dynamics
- Interference effect in the entrance channel of reaction
- Interference effect in the exit channel of reaction
- Experimental techniques
- Data evaluation and preliminary results

Introduction

- More than 65 years ago Otto Hahn, Lise Meitner and Fritz Strassmann have discovered the **nuclear fission** process. Nevertheless today we still do not know very much about some of the fundamental aspects of fission.
- For example – we know that fission of the nucleus is accompanied by the emission of **prompt neutrons (PFN)**. The angular distribution of such neutrons relative to the fission axis can be described at least by two components: most of them are elongated along the fission axis, while another part shows approximately a spherically symmetric distribution. It's evident that the first ones are evaporated by the completely accelerated excited fission fragments because the elongation can be the result of velocities summation.

Introduction

- Now we must mention that there is one exotic mode of fission, which is called “**ternary fission**”. This is the fission of two fragments accompanied by the emission of a charged light particles like as p, d, t, 3He, 4He, 5He and so on. The angular and energy distribution of this particles shows that they are emitted from the region between the two fragments. The most models of ternary fission describe it as evaporation from neck at the scission point. But why does not ternary fission include neutrons? The evaporation of a neutron is more easy than of a proton, because for the former there is no Coulomb barrier.

Introduction

What is the nature of second part ? A spherically symmetric distribution means that they evaporated by the nucleus before rupture of the neck at the scission point. So they were called “**scission neutrons**”.

Introduction

- **Is a scission neutron the neutral component of ternary fission?** It’s not so easy to answer because in experiments it is practically impossible to distinguish between them and fragment neutrons due to the overlap of the energy-angular distributions. A lot of analysis has been performed to evaluate the probability of scission neutron evaporation. The ratio of scission neutron to total number of PFN is varies from 1% till 35%! It’s a result of arbitrary assumptions made in different analyses. Thus it’s high time to work out an alternative method to search for the scission neutrons.

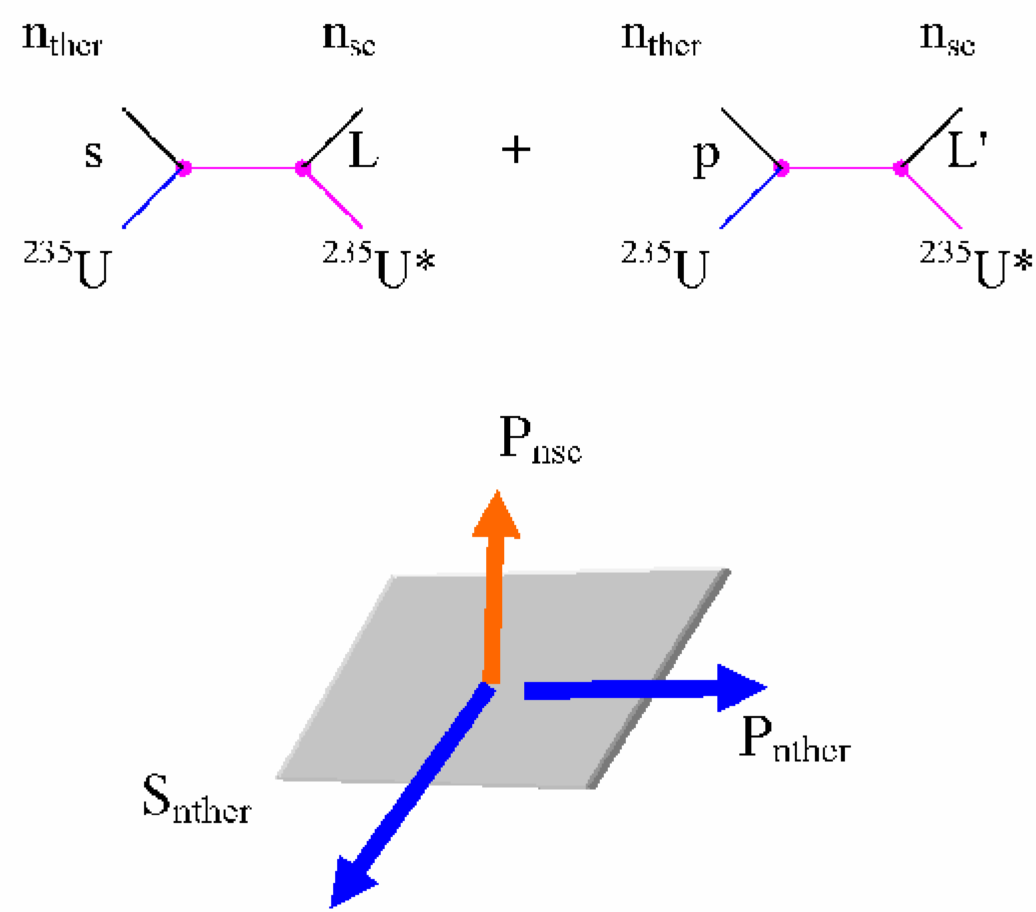
Specific angular correlations as a tool to search for scission neutrons

- It's well known that any angular correlation is a result of the orbital momenta interference. So because this is a quantum-mechanical effect both, the magnitude and the sign of the correlation coefficients, depend on the quantum numbers of the initial and final state as well as on quantum characteristic of the outgoing particle. When the condition of the experiment does not allow us to choose a definite quantum state (initial or/and final) the observables will be the result of averaging over all N states involved in reaction. It means that any coefficient will be suppressed by a factor $1/N^{1/2}$.

Specific angular correlation as a tool to study fission dynamics

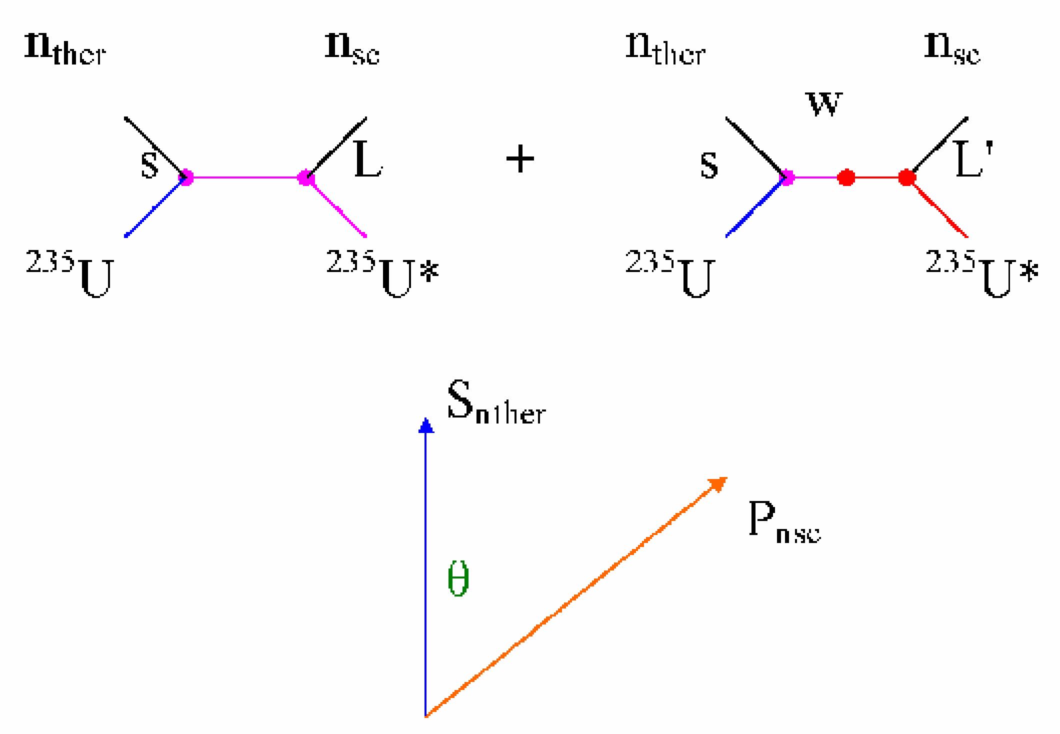
- Concerning fission it must be emphasized that the number of fragment's final states is an order of 10^8. Therefore any angular correlation of particles emitted by fragments will vanish.
- In contrast, the number of initial states of the scission neutron should be rather small because they are evaporated by cold strongly deformed fissile nucleus. Thus a scission neutron can possess a non vanishing angular correlation with the spin of the compound nucleus. This is the main idea of our approach how to distinguish between scission and fragment neutrons.

sp-interference effect
in the entrance channel of reaction

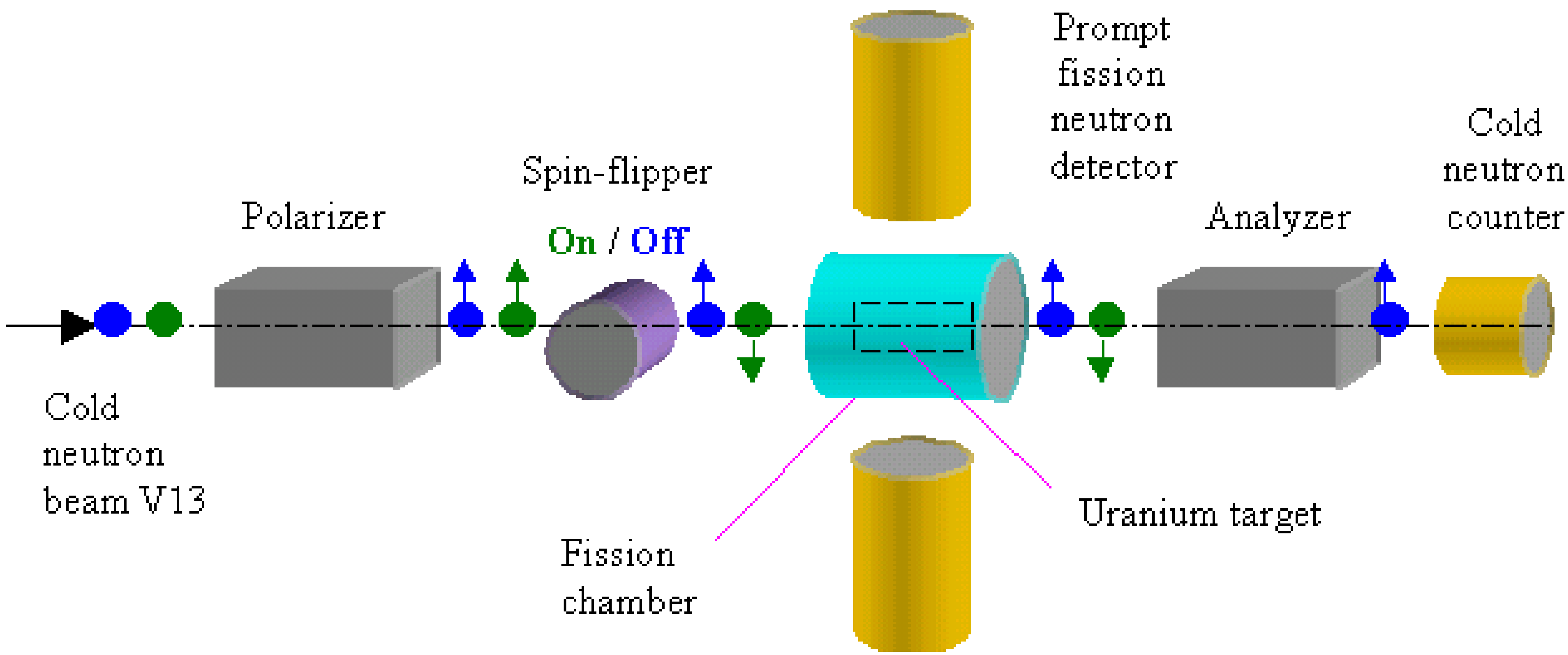


$$W = C \cdot (1 + B_n \cdot \mathbf{P}_{nsc} \cdot [\mathbf{P}_{nther} \times \mathbf{S}_{nther}])$$

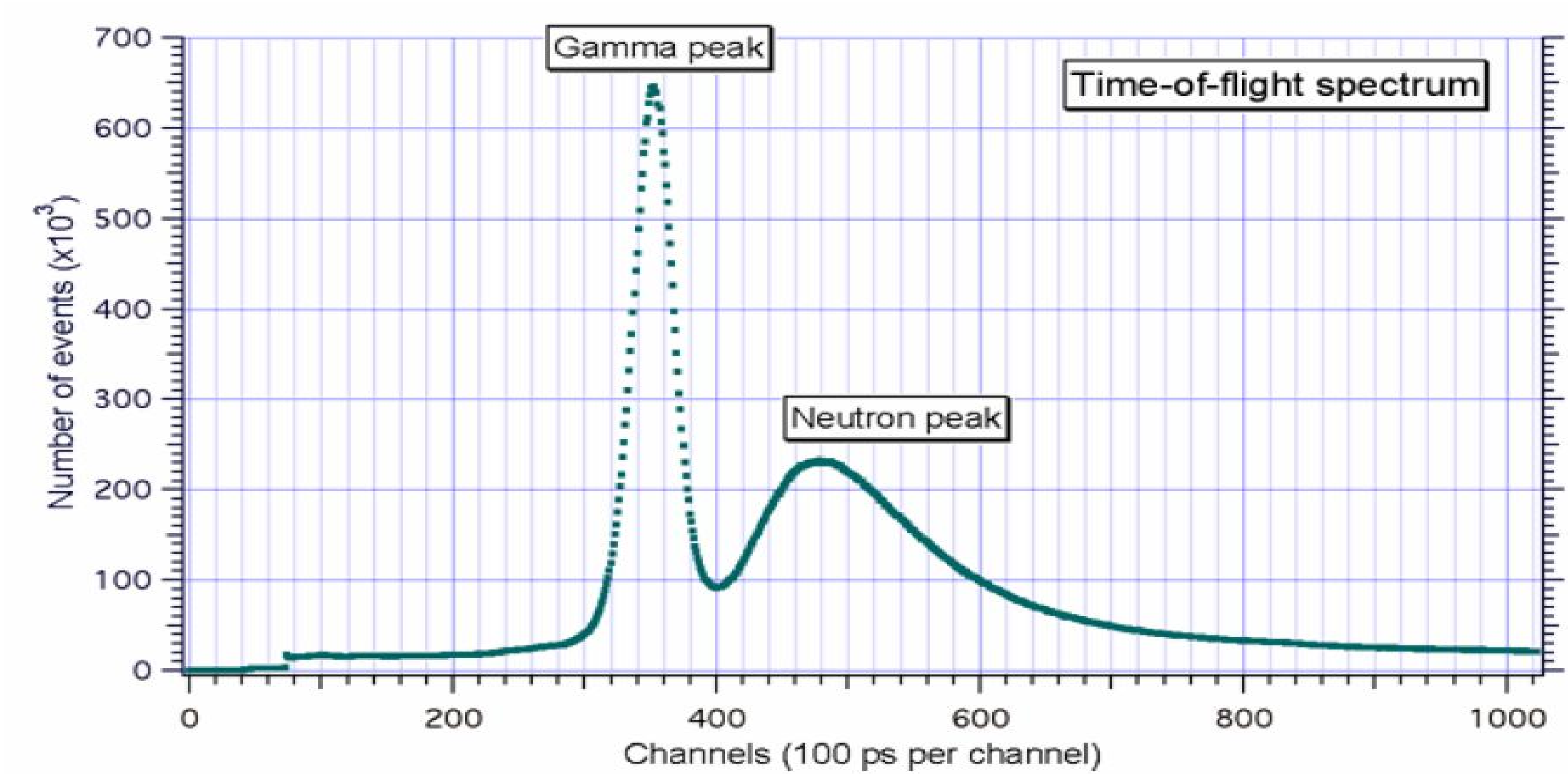
P-odd correlation
Interference effect in the exit channel of reaction

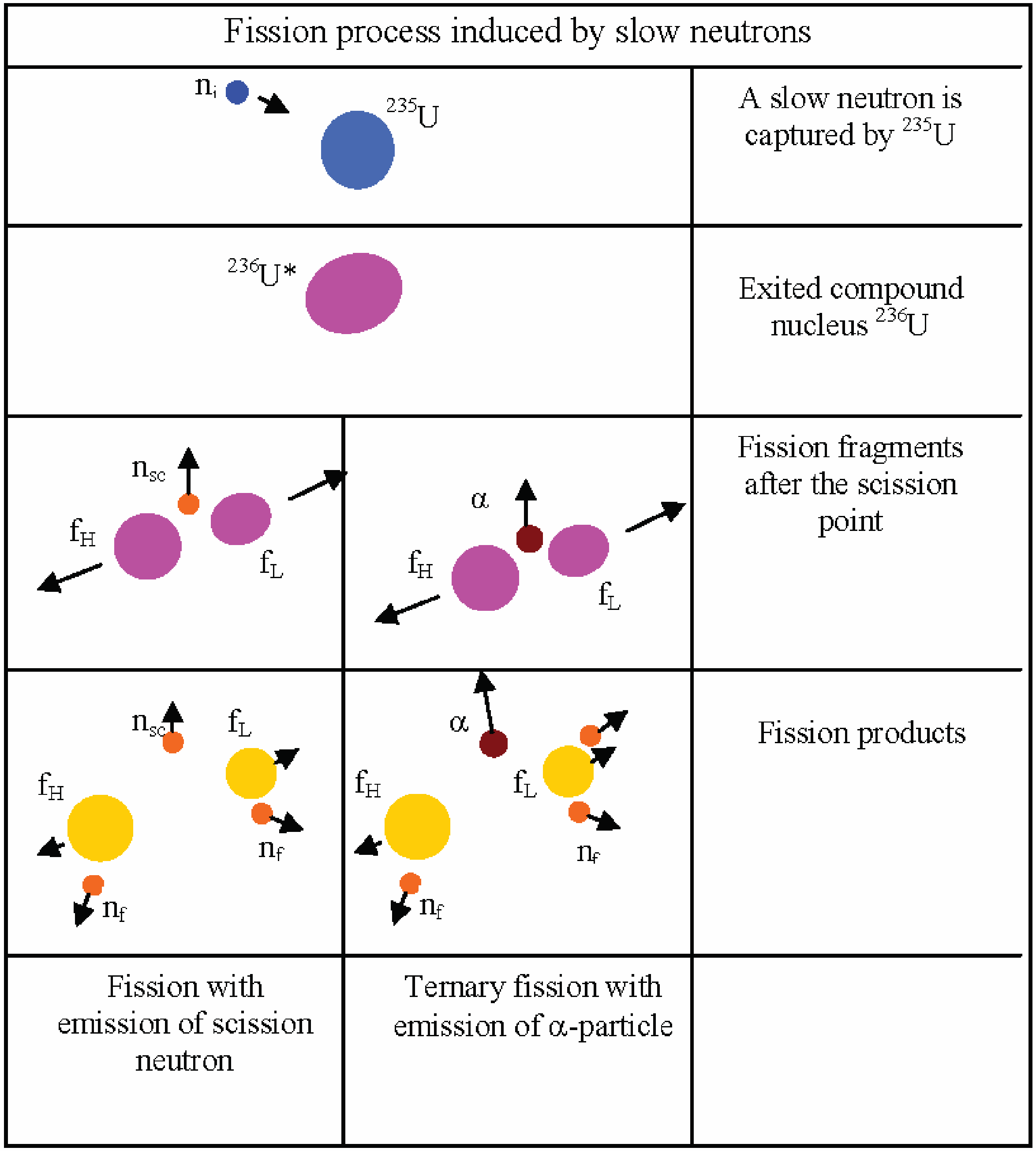


Experimental setup



Delayed coincidence spectrum




Fission process induced by slow neutrons
n_i
^{235}U
A slow neutron is captured by ^{235}U
$^{236}U^*$
Exited compound nucleus ^{236}U
n_{sc}
f_H
f_L
α
f_H
f_L
Fission fragments after the scission point
n_{sc}
f_L
f_H
n_f
n_f
α
f_H
f_L
n_f
n_f
Fission products
Fission with emission of scission neutron
Ternary fission with emission of α-particle