Preliminary results on direct observation of true ternary fission in the reaction $^{232}$Th+d (10MeV)

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Conventional ternary fission \( \sim 10^{-3}/\text{bin. fiss.} \)

"Polar emission" \( \sim 10^{-5}/\text{bin. fiss.} \)

Ternary fission of low excited nuclear systems - status quo:

True ternary fission - contradictory results:

- M.L. Muga et al., (1967) - \( Y_3 \sim 10^{-6}/\text{bin. fiss.} \), but it was strongly criticized;
- P. Schall, P. Heeg,
- M. Mutterer, J.P. Theobald (1987) - \( Y_3 < 10^{-8}/\text{bin.fiss.} \)
Our experiments in FLNR and FLNP (Dubna, Russia), in JYFL (Jyväskylä, Finland) in the frame of the “missing mass” method:

strong indications on true ternary fission with almost collinear kinematics of the products and clustering as a physical reason of the process.

We called this decay channel as “collinear cluster tripartition (CCT)” due to the features listed.

\[ \max Y_{\text{CCT}} \sim 4 \times 10^{-3}/\text{bin. fiss.} \]

See our posters here and publications at [http://fobos.jinr.ru](http://fobos.jinr.ru) for details.

Prescission configurations revealed in the CCT channel
From “missing mass” → to direct registration of all decay products – studying of the $^{232}\text{Th}+\text{d}$ (10MeV) reaction in ATOMKI

FLNR-ATOMKI collaboration

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ATOMKI, June 2008
Experimental setup: MCP based timing detectors and 2 mosaics of 9 PIN-diodes each

Data array $5.5 \times 10^6$
Ternary decay events & velocity correction

\[ V_{\text{emis}} = \frac{22}{\left( \frac{17}{V_{\text{exp}}^{B}} + \frac{5}{V_{C}} \right)} \]

\[ \Theta_{\text{max}} \approx 10^0 \]

M1 > M2 > M3

\[ \text{Ms} = 234 \text{amu} \]
Comparison with the data of M.L. Muga et al.

Muga: $Y_3 \sim 10^{-6}$/ bin. fission
Our res.: $Y_3 \sim 10^{-5}$/ bin. fission

Good agreement of E & M spectra
Comparison of the results obtained at “Diogenes” and that found by M.L. Muga et al. for $^{252}$Cf(sf)

Fig. 1. Schematic drawing showing one of the sectors of the gridded ionization chamber. The position sensitive cathode measures fragment emission angles with respect to the fission source, with a resolution of $\leq 2^\circ$ fwhm.

The measured energy spectrum of ternary fragments, unlike the mass spectrum, agrees quite well with that found by Muga et al. for $^{252}$Cf.

Possible reason of the discrepancy:

momentum conservation law was used for calculation of the FF masses in both cases, but different source backings were used.
Bearing in mind our results at least this point of criticism of Muga results is overcame.

Alternative Evaluation of Ternary-Fission Data*

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The difficulty of the experiments carried out by Muga and co-workers and of obtaining statistically significant data is not to be underestimated. However, advances in the technology of time-of-flight techniques and the understanding of pulse-height defects in semiconductor detectors may now permit a relatively simple differentiation between a uranium recoil fragment and a light-ternary-fission fragment.
Filling the Gap between Ternary and Superasymmetric Fission
(F. Goennennwein, private communication, March 2009)

ILL Data Grenoble
Thermal neutron induced fission
Lohengrin Separator

GSI Data Darmstadt
750 AMeV $^{238}$U beam, FRS separator
Be-Target: nuclear excitation ($\approx 27$ MeV)
Pb-Target: electromagnetic excitation ($\approx 11$ MeV)


ILL Collaboration
Our previous experiments in the frame of the “missing mass” approach: bump in the FF mass-mass distribution.
Bump in $^{252}\text{Cf}(sf)$

Results of processing with second derivative filter

ridges $Ma+Mb=\text{const}$ which are equal, presumably, to the masses of magic clusters (Ni, Ge, Sn)
Comparison of the internal bump structures: $^{252}\text{Cf} - ^{236}\text{U}^*$

Two systems, 16 amu difference in masses, but
- the same bump parameters,
- similar relative yields $\sim 10^{-3}$

magic clusters of
Ni, Ge, Sn
are decisive for the bump structure
Direct evidence for the structure $M_1 + M_2 = \text{const}$ in $^{236}\text{U}^*$

Selection using $dE$ or $Z$ gate – distribution is almost free from the background
Clustering as a reason of ternary decays

For the first time both in spontaneous and induced fission we observe the mode of ternary decay with almost collinear recession of the products similar by physics to known heavy ion radioactivity (cluster decay).

Sharp increase of the yield for the partition 132/80 (M.L. Muga et al.)
What about angular distribution of the effect?

Δt \rightarrow 0 - prompt ternary break-up
Φ \rightarrow π/2
(results of M.L. Muga et al.)

Δt \rightarrow \infty - sequential ternary fission
Φ \rightarrow 0
(our results – collinear tri-partition)
Extremely high yield of the effect – why?

Valley of heavy ion radioactivity – huge barrier, low yield

Clustering at large elongations → CCT, high yield


А.В. Унжакова, В.В. Пашкевич, Ю.В. Пятков, Изв. АН сер. Физ. т.60 (1996) 30
Conclusions

1. Preformation of the three-body molecule based on magic clusters is a physical reason of the true ternary fission.

2. Extremely high yield of the ternary cluster decay reference to known Lead radioactivity is due to the elongated (chain-like) prescission configuration.

3. Wide angular distribution of the fragments in true ternary fission (CCT) is likely reflects also large scale of the time delay between two ruptures in the prescission chain-like configuration: prompt ternary breakup leads to the maximal angles between the products while sequential fission is decisive for their collinear kinematics.