Probing the decay mechanism of hot nuclei by Coulomb chronometry

Diego Gruyter

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Collisions between Coulomb and Fermi energies
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Collisions between Coulomb and Fermi energies

Coulomb barrier
Fission/Evaporation

Available energy
Fermi energies

adapted from P. Möller et al.
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Coulomb barrier

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Fermi energies

Multifragmentation

Available energy

adapted from M. Colonna et al.
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Collisions between Coulomb and Fermi energies

Coulomb barrier → This work → Fermi energies

Fission/Evaporation → Multifragmentation

Available energy


Multifragment production in Xe+Sn central collisions

Studied reactions
- Xe+Sn at 8, 12, 15, 18, 20, 25 MeV/A
- Measured with INDRA at GANIL
- Fusion-like events

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![Graph showing the production rate of fragments as a function of Xenon beam energy.]

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- Precursor of multifragmentation?
- Estimation of the involved timescales

Probing the decay mechanism of hot nuclei by Coulomb chronometry

From hot sequential fission to multifragmentation

$t = t_0$

$t = t_0 + \delta t$

Experimental results
- Two successive binary splittings
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- Successive splittings occurring on shorter and shorter time scale
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Decay mechanism

- Successive splittings occurring on shorter and shorter time scale
- Compatible with simultaneous break-up above $E_b = 20\text{ MeV}/\text{A}$
- Onset of multifragmentation above $E^* = 4.0 \pm 0.5\text{ MeV}/\text{A}$
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**Coulomb chronometry to probe the decay mechanism of heavy nuclei**

**Reaction and decay mechanism**

In heavy ion collisions at bombarding energies around 10–20 MeV/A, the production of 3-fragment events has been studied. At the lowest beam energy, the 3-fragment exit channel is observed as the beam energy increases (fig.1). The decay mechanism responsible for these 3-fragment events is not well established: Is it the continuation of low energy fission or the precursor of high energy simultaneous fragmentation?

**Experimental analysis.** We investigated the 3-fragment exit channel in fusion-like events produced in Xe+Sn central collisions at 12, 15, 18, 20, and 25 MeV/A. Data were measured with the INDRA detector.

**Chronometer.** Identification of the sequence. It has successive splitting stages. When possible, we measure θ=90°. Experimentally, this maximum is more pronounced as the beam energy increases (fig.5). We compare the relative velocity between each pair of fragments with that expected for fission-like systems.

**Inter-splitting time.** In the lowest beam energies, the inter-splitting time is calculated as the time delay between the production of the first fragment, which is measured by the time of flight system, and the production of all the subsequent fragments. If the inter-splitting time is modified by the Coulomb field, the second fragment present a random angular distribution and presents a maximum. We observe a clear decrease of the inter-splitting time with increasing beam energy (fig.9). We quantify the effect by the Coulomb distortion δv (fig.6).

**Time scale.** The inter-splitting time can be translated in terms of time scale. The associated Coulomb distance sc is calculated from the Coulomb distortion δv (fig.7).

**Coulomb chronometry**

<table>
<thead>
<tr>
<th>Time scale</th>
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<tr>
<td>Inter-splitting time</td>
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<td>Experiment</td>
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<tr>
<td>Simulation</td>
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**From sequential to simultaneous**

**Method.** For each event we calculate P₁, P₂, and we fill them in a Dalitz plot (fig.2). It measures the compatibility with the sequence.

**Interpretation.** When increasing beam energy, the three heavy fragments production becomes more and more simultaneous.

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