Probing the Stability of Superheavy Nuclei with Radioactive Ion Beams

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How to Access the N=184 region?

- can be reached with n-rich RIBs, but:
  - small ER cross-sections
  - small RIB intensities
Synthesis of Neutron-rich Isotopes with RIBs?

More neutrons does not mean larger fusion residue cross-sections. Example: $^{32}$Ge + $^{208}$Pb $\rightarrow$ $^{114}$

(Theorie: G. Adamian, N. Antonenko, W. Scheid, DNS model)

Expected yields for $\sigma = 0.1$ pb and $10^9$ proj./s: 1 event in 300 years
The Fusion Process in Heavy Systems

10 - 100 mb

Composite System

QUASI-FISSION (QF)

FUSION

Compound Nucleus (CN)

FUSION-FISSION (FF)

Evaporation Residue (ER)

Fission Fragments

\[ \sigma_{ER} = \sigma_{\text{capture}} \cdot P_{CN} \cdot P_{\text{survival}} \]

Superheavy systems: \( \sigma_{ER} \ll \sigma_{\text{capture}} \) \( \Rightarrow \) \( \sigma_{\text{capture}} \approx \sigma_{QF} + \sigma_{FF} = 10 - 100 \text{ mb} \)
The Fusion Process in Heavy Systems

Movement of the nuclear system on the potential energy surface

example: 48Ca + 248Cm

- Study of QF and FF allows the „mapping“ of the potential energy surface
- expected yields for $\sigma = 100$ mb and $10^6$ proj. / s: $\sim 300$ / hour
- experiments are possible in very near future at HIE-ISOLDE, CERN
The HIE-ISOLDE Project at CERN

HIE-ISOLDE: an energy, intensity and quality upgrade

Timeline:
♦ 2015: installation of LINAC stage 1 + beamlines; first beam in October 2015 (up to 5.5 MeV/u)
♦ 2016: LINAC stage 2 and 3: beam energies up to 10 MeV/u
Our first experiment at HIE-ISOLDE

The reaction $^A$Rb + $^{209}$Bi $\rightarrow$ $^A$120$^*$

- Rb beams are available in a broad range of N and with high intensities
- With $^{95}$Rb the N = 184 shell can be reached

$E^\ast_{CN} = E_{cm} - Q$
$E_{cm} = B_{fu}$

$E^\ast_{CN} < S_n \approx 10 \text{ MeV} \rightarrow \text{no neutron evaporation}$
$E^\ast_{CN} < B_f \approx 5 \text{ MeV} \rightarrow \text{no CN fission}$
$E^\ast_{CN} < 0 \rightarrow \text{no CN formation}$

figure: CERN web page
Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Study of the Di-nuclear System \(^{ARb} + ^{209}Bi\) (\(Z_1 + Z_2 = 120\))

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Decision of the CERN INTC, December 2012:

"... formation of the capture probability. The two-arm CORSET setup providing mass- and energy information will be employed at 3 different \(^{95}Rb\) beam energies. The proposal is very interesting and will initiate a new program at ISOLDE. It was requested that stable Rb beam be used for ..."
Experimental Setup for the Study of $^7\text{Arb} + ^{209}\text{Bi}$

CORSET detection system, Dubna (E. Kozulin et al.)

Experimental program:
Measurement of $A$ - TKE distributions of as a function of projectile neutron number and beam energy
The Heaviest Known Nuclei

\[ ^{239}_{15} \text{Rb} + ^{209}_{83} \text{Bi} \text{ composite systems reachable Rb RIBs of intensity }> 5 \cdot 10^6 \text{ / spill} \]
Summary

The N=184 shell cannot be reached on mid-term time scale in fusion-evaporation reactions with RIBs.

But: QF and FF appear with large cross-sections of ~100 mb and allow the probing of the PES possible with RIB intensities ≥ 10^6 part./s.

RIBs with energies up to >5 MeV/u available at HIE-ISOLDE (CERN) starting from late 2015.