Compound-Nuclear Reactions and Related Topics (CNR*24)
Jul 8 – 12, 2024 Vienna International Center

Study of the target-deformation impact on the optimal beam energy for the ^{51}V +^{159}Tb fusion-evaporation reaction.

P. Brionnet, H. Haba, D. Kaji, S. Kimura, K. Morimoto, T. Niwase, S. Sakaguchi, H. Sakai

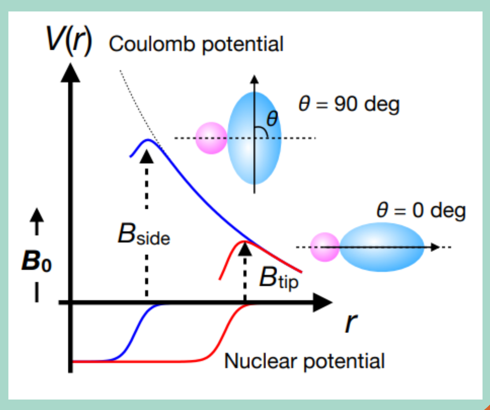
Context of the study

The search for new elements beyond oganesson (Z=118) needs the use of beams heavier than ^{48}**Ca** on actinide targets and hot-fusion reactions: ^{50}**Ti**, ^{51}**V**, or ^{54}**Cr**. The search for Z=119 is underway at RIKEN [1], using the ^{51}**V**+^{248}**Cm**→^{299}**119*** reaction. However, limited information regarding reaction parameters and the effect of **target deformation** with projectiles heavier than ^{48}Ca is currently known. The ^{51}**V**+^{159}**Tb**→^{210}**Ra*** reaction has been investigated through both quasielastic barrier distribution and excitation function measurements to study the **optimal beam energy**, and the effect of **target deformation**.

Goal of the study

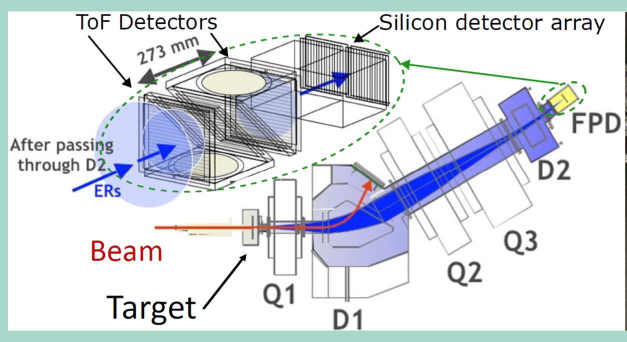
Expand the systematic study of the quasielastic barrier distribution and the so-called **"side-collision configuration** effect/energy" [2-3], observed in hot-fusion reactions on **prolate-deformed actinide targets:** optimal beam energy linked to the **side-collision configuration** rather than the **tip-to-tip collision configuration**.

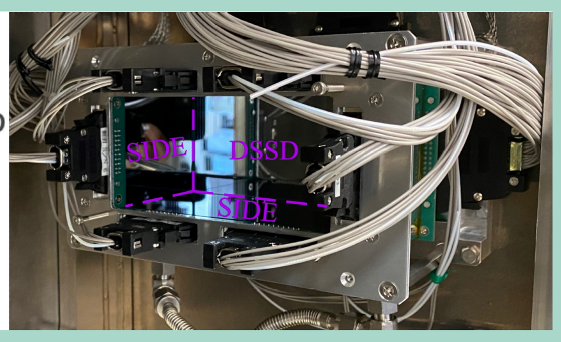
The objective of this work is to investigate whether this effect is observed with **similarly deformed lighter targets** : ^{159}**Tb**



Experimental Setup and Method

The experiment was done using the **GARIS-III** separator/setup coupled with the newly upgraded **SRILAC accelerator** [1].





GARIS-III Setup [1]:

- Gas Field Separator: Q-D-Q-Q-D configuration
- Focal plane detection system:
  - Two Time-of-Flight (ToF) detectors.
  - Six Silicon detectors in a box configuration.

Experimental Method [2-3]:

- **Quasielastic barrier distribution:** Transport the recoiled **target-like nucleus at 0°**.
- **Excitation function measurement**: Transport of the **evaporation residue**.
- **Dose**: **Rutherford scattering** of ^{51}V at 45° at the target position.

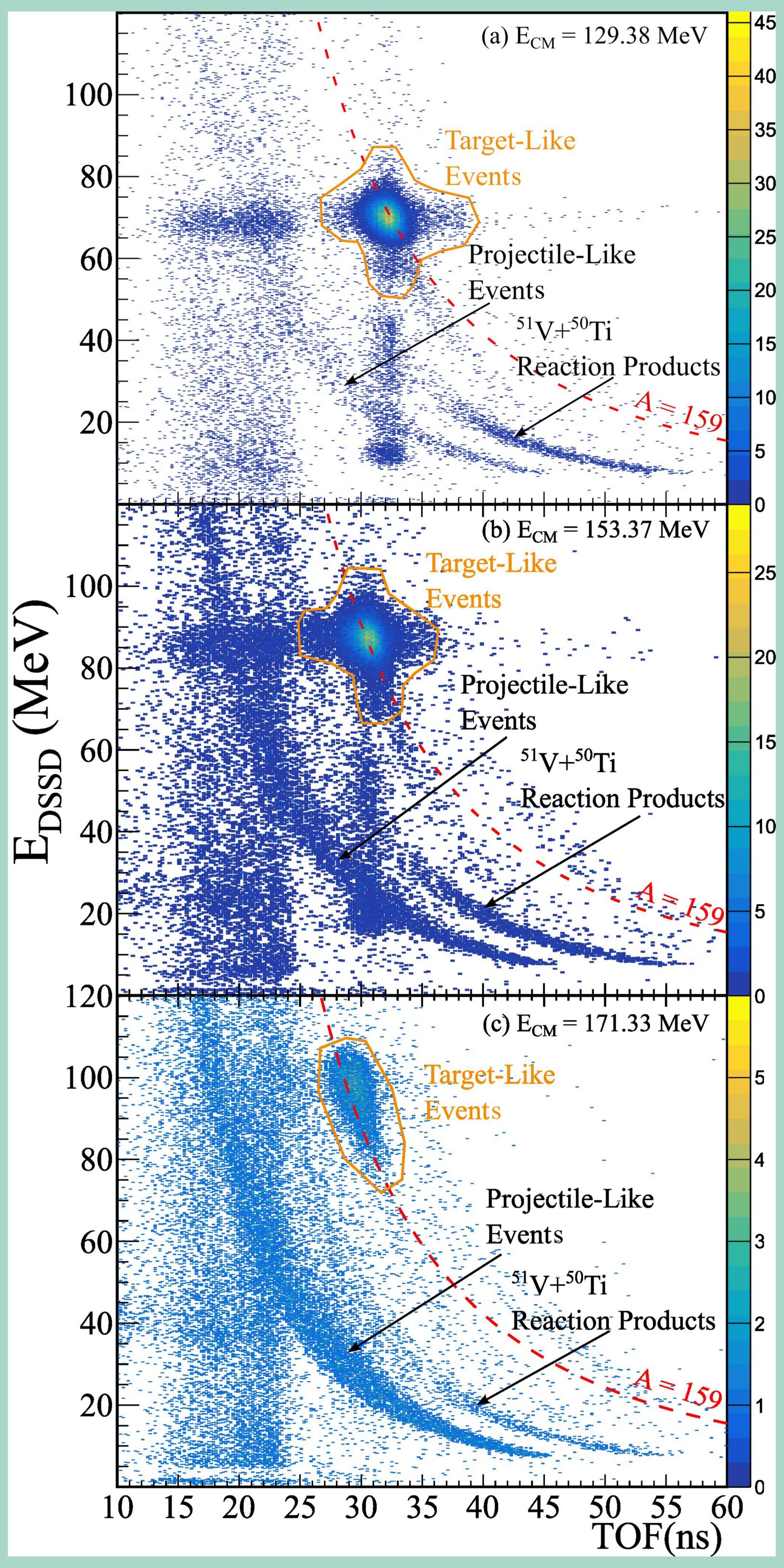
Experimental conditions:

- Beam $^{51}V^{13+}$ intensity:
  - 1.54 pnA (barrier distribution).
  - 150 to 350 pnA (excitation function).
- Metallic ^{159}Tb on 2.83 μm titanium backing:
  - 293±10 μg.cm^{-2} (barrier distribution).
  - 363.8±16.3 μg.cm^{-2} (excitation function).

References

[1] H. Sakai, H et al., Eur. Phys. J. A 58, 238 (2022).
[2] M. Tanaka et al., J. Phy. Soc. Jpn, 91, 084201 (2022).
[3] T. Tanaka et al., Phys. Rev. Lett. 124, 052502 (2020).
[4] K. Hagino et al., Comput. Phys. Commun. 123, 143 (1999).
[5] T. Cap, M. Kowal, K. Siwek-Wilczynska, Eur. Phys. J. A (2022) 8:5231

Barrier Distrubtion Restults



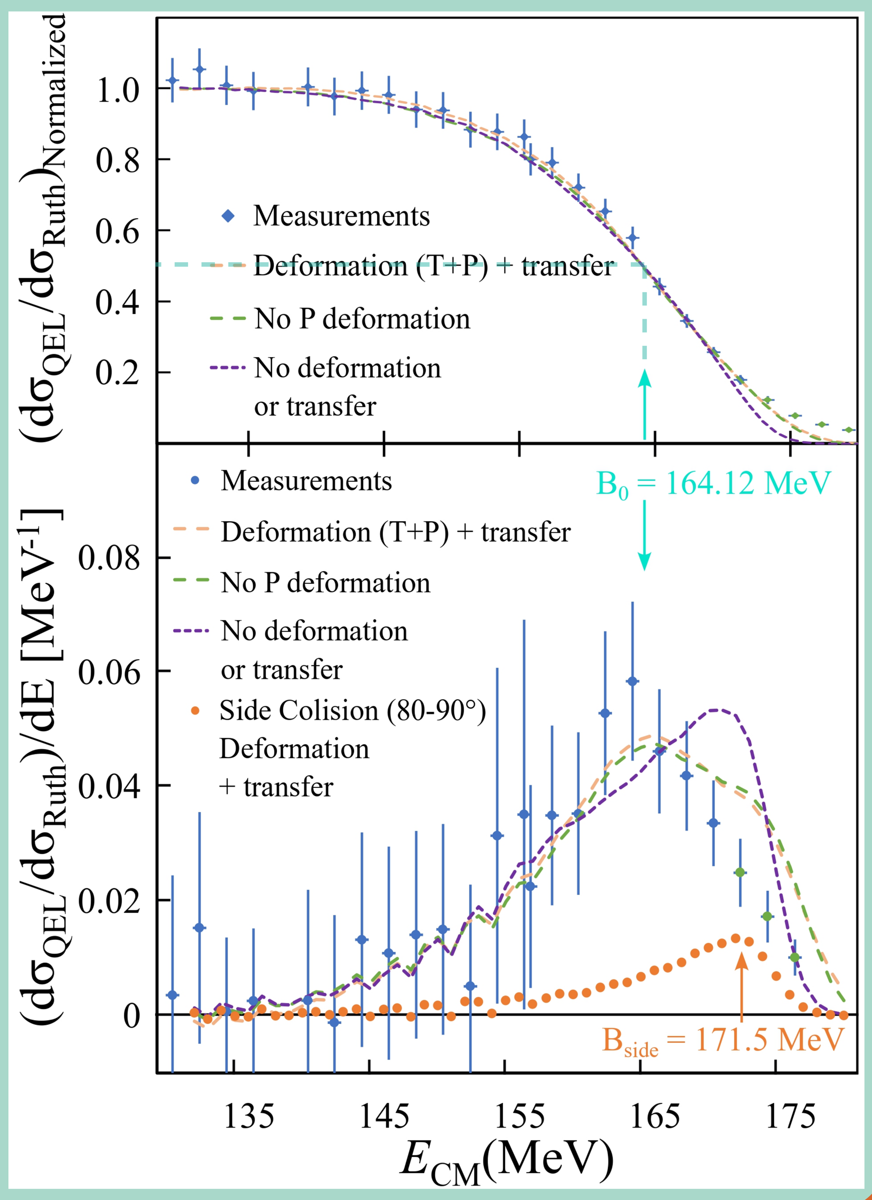
The **quasielastic barrier distribution** measurement was perfomed by identifying the **target-like** nuclei at the focal plane:

- **Time-Of-Flight** and **implantation energy** correlation (left figure): **Target-like identification** (A=159, red dashed line) $\mathbf{N_{QE}[^{159}Tb]}$, and rejection of other contaminants.
- **Centering** of the implantation distribution for **transmission correction.**
- Normalization to the **dose** $\mathbf{N_{Ruth}[^{51}V]}$.
- **Contamination** of **deep-inelastic** events at energies above the average Coulomb barrier (green points in the bottom figures).

The quasielastic barrier distribution ***D(E)*** (bottom) is extracted using the reflection probability ***R(E)*** (top):

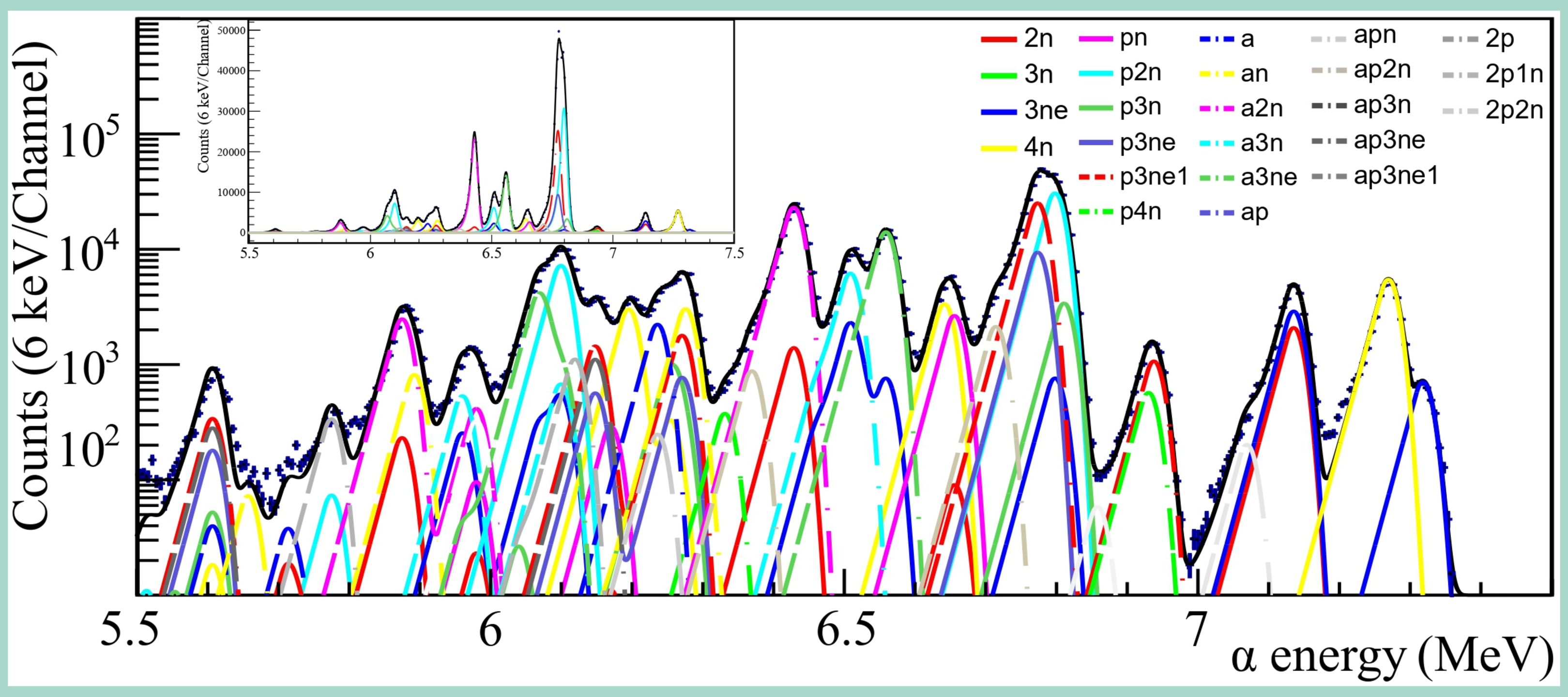
$$R \equiv C \times \frac{N_{QE}[^{159}\mathrm{Tb}]}{N_{Ruth}[^{51}\mathrm{V}]}$$

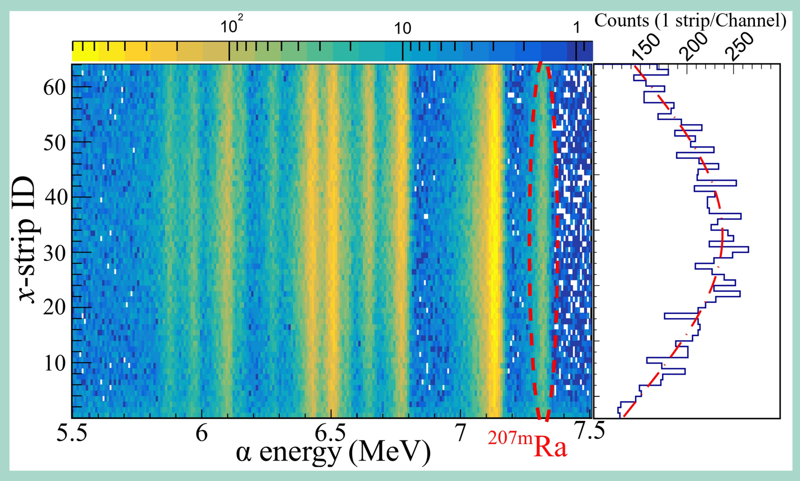
$$D(E) = -\frac{dR}{dE} \equiv -\frac{d}{dE}\left(\frac{d\sigma_{QE}}{d\sigma_{Ruth}}\right)$$



- The **average Coulomb barrier height** ($\mathbf{B_0}$) is extracted from the **R(*E*)** distribution: $\mathbf{B_0}$ **= 164 MeV** (blue arrow/lines).
- The **CCFULL Code** [4] was used, and the parameters were optimized to reproduce the measured distribution and extract the **side-collision energy:** $\mathbf{B_{side}}$ **= 171.5 MeV** (orange points/arrow).

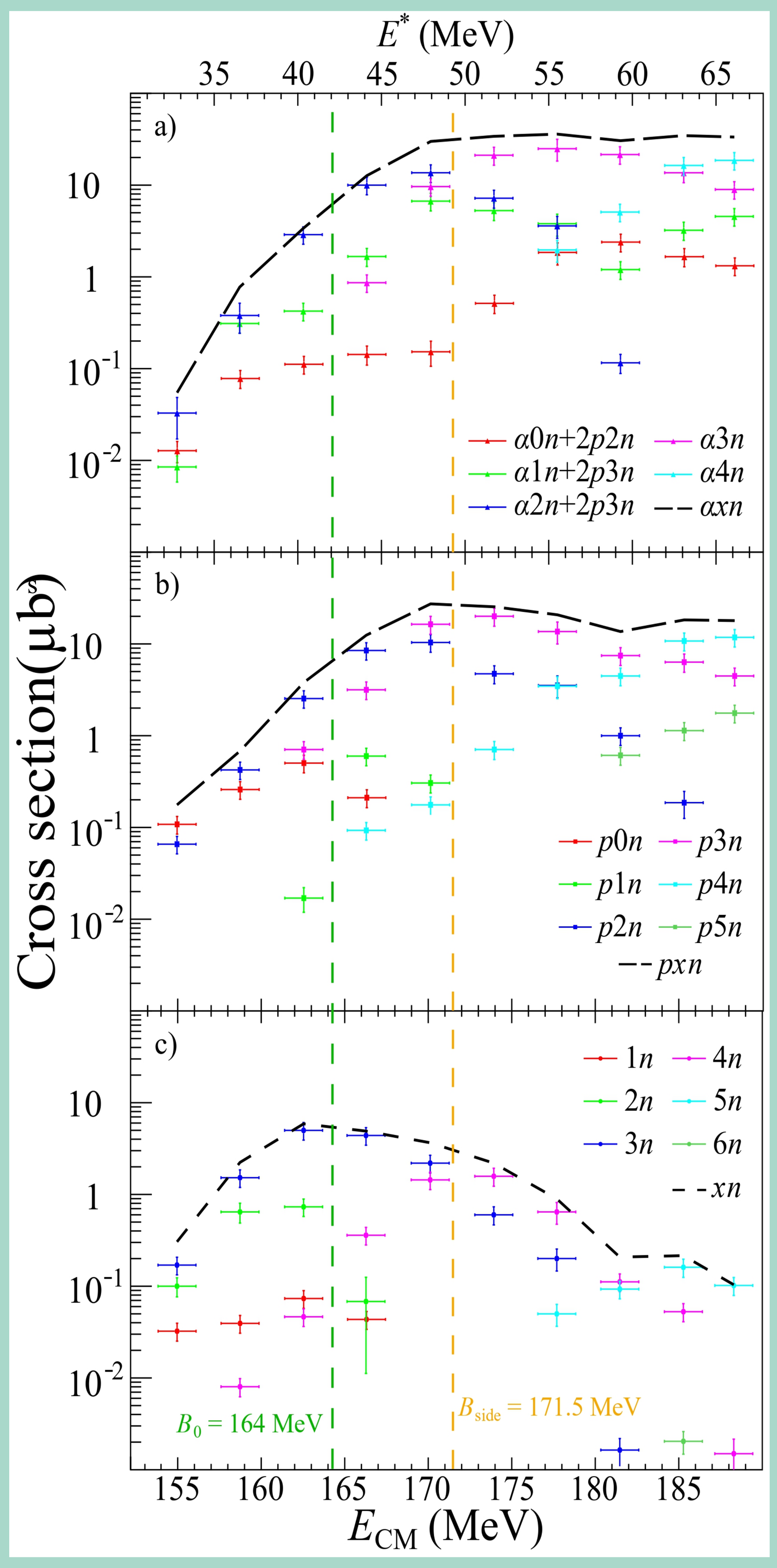
Excitation Function Results





The **excitation function** measurement was perfomed using the decays at the focal plane:

- **α-spectrum only**, accumulated over 24 hours, without decay time selection.
- **Overall spectrum fit** (top left figure) using the **reported** decay **properties/errors**: For each exit channel (xn, pxn, αxn, ...), the theoretical spectrum fit function (colored lines) was used to extract all the populations **simultaneously**.
- **Transmission correction**:
  - Dispersion of the implantation profile (top right figure).
  - Monte Carlo simulation of the particle evaporation: angular distribution.
- **Enhancement of the charged particles channels**:
  - σ(α3n) = **41.7±5 μb**, σ(p3n) = **36.3±5 μb**, and σ(3n) = **4.7±1.5 μb**.
- **Maximum of the *xn*** channels: consistent with the **average barrier height** $\mathbf{B_0}$**=164 MeV** and **NOT** with the side-collision energy $\mathbf{B_{side}}$**=171.5 MeV**.



The discussion and interpretation of this enhancement of charge particle evaporation and orientation effect are currently ongoing using a statistical model [5].