

Cluster-transfer reactions with radioactive ^{98}Rb and ^{98}Sr beams on a ^7Li target

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- **Introduction:**

- Why cluster transfer reactions with RIBs?
- The experiment at REX-ISOLDE

- **γ spectroscopy**

- **Reaction mechanism:**

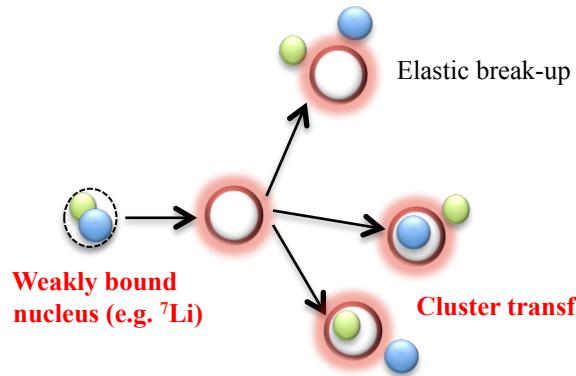
- Experimental observables
- Theoretical interpretation

- **Conclusions and future perspectives**



Why cluster-transfer reactions with RIBs?

- **Cluster-transfer reactions:**



- **Possible advantages:**

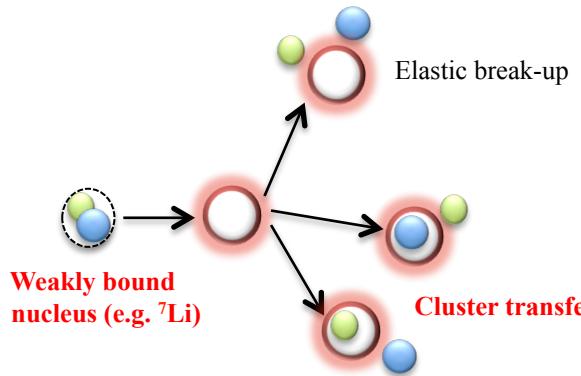
- Study of new mass regions
- Probe of different nuclear structures
- Population of Yrast and off-Yrast states
- Medium high spin-energy states

- **Particularly suitable to study n-rich nuclei**

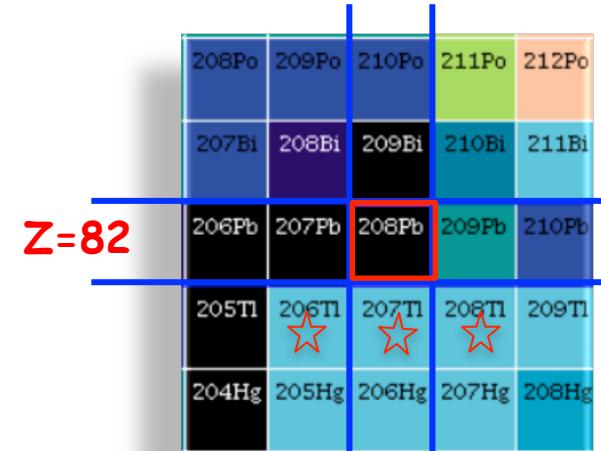
- **Never tested so far with RIBs**

Why cluster-transfer reactions with RIBs?

- Cluster-transfer reactions:



- Near magic nuclei ^{208}Pb and ^{132}Sn :

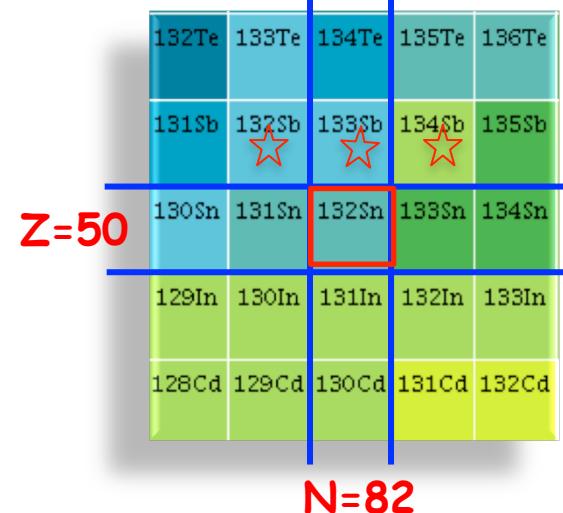


- Possible advantages:

- Study of new mass regions
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- Population of Yrast and off-Yrast states
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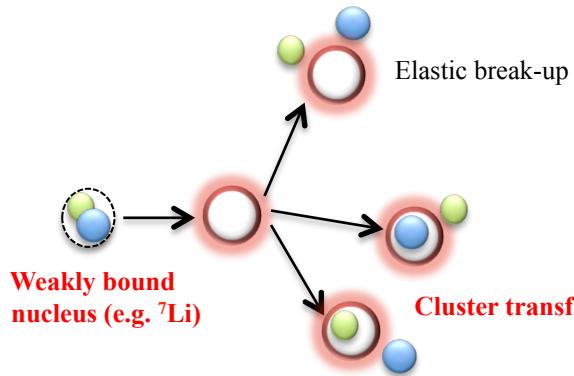
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Why cluster-transfer reactions with RIBs?

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- Possible advantages:

- Study of new mass regions
- Probe of different nuclear structures
- Population of Yrast and off-Yrast states
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TEST CASE: $^{98}\text{Rb}+^7\text{Li}$ @ 2.85 MeV/A

- Near magic nuclei ^{208}Pb and ^{132}Sn :



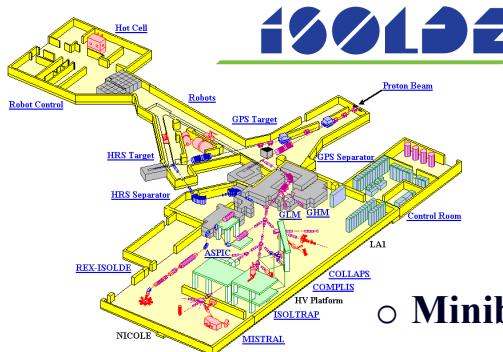
- The reaction

$^{98}\text{Rb}/^{98}\text{Sr} + ^7\text{Li}$ @ 2.85 MeV/A

- Details of the experiment

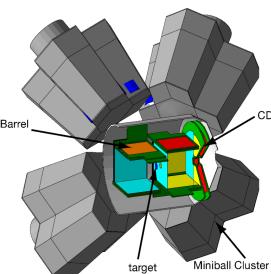
- Beam composition: $\approx 60\% {}^{98}\text{Rb}$ & $40\% {}^{98}\text{Sr}$
- Beam intensity: $2.4 \cdot 10^4$ pps
- Target: 1.5 mg/cm^2 LiF

- The experimental setup



- Miniball

- 7 triple clusters (113 segments)
- $\varepsilon = 5\%$ @ 1 MeV



- FCD from T-REX :

- Distance: 22 mm
- $24^\circ < \theta_{\text{lab}} < 65^\circ$

The experiment

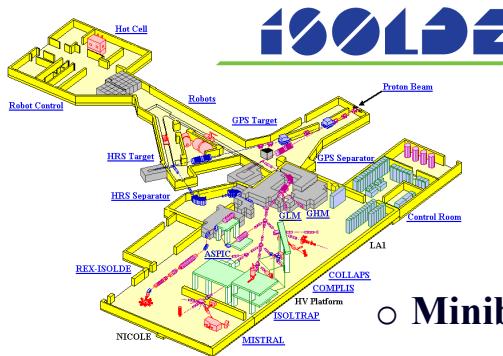
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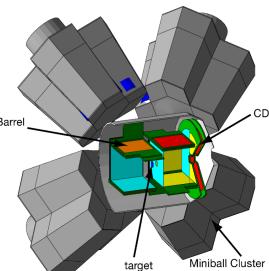
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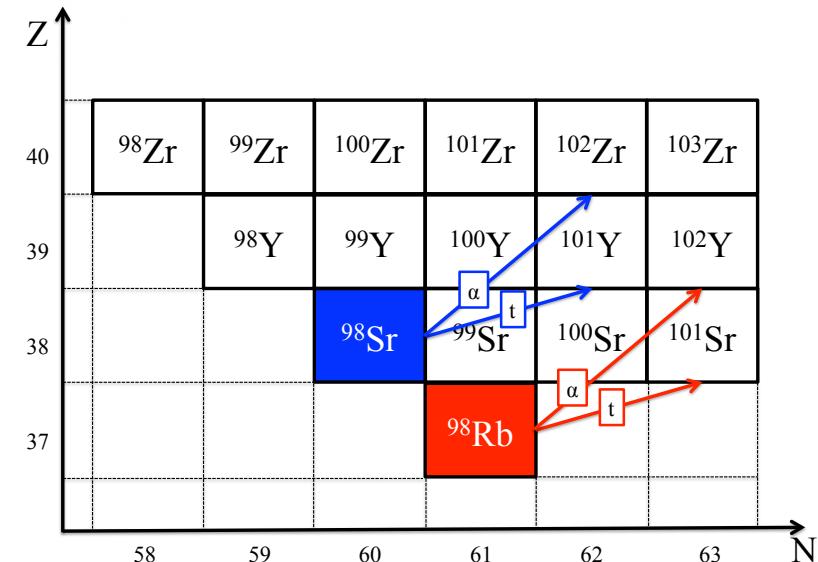
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- FCD from T-REX :

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- Aim of the experiment:

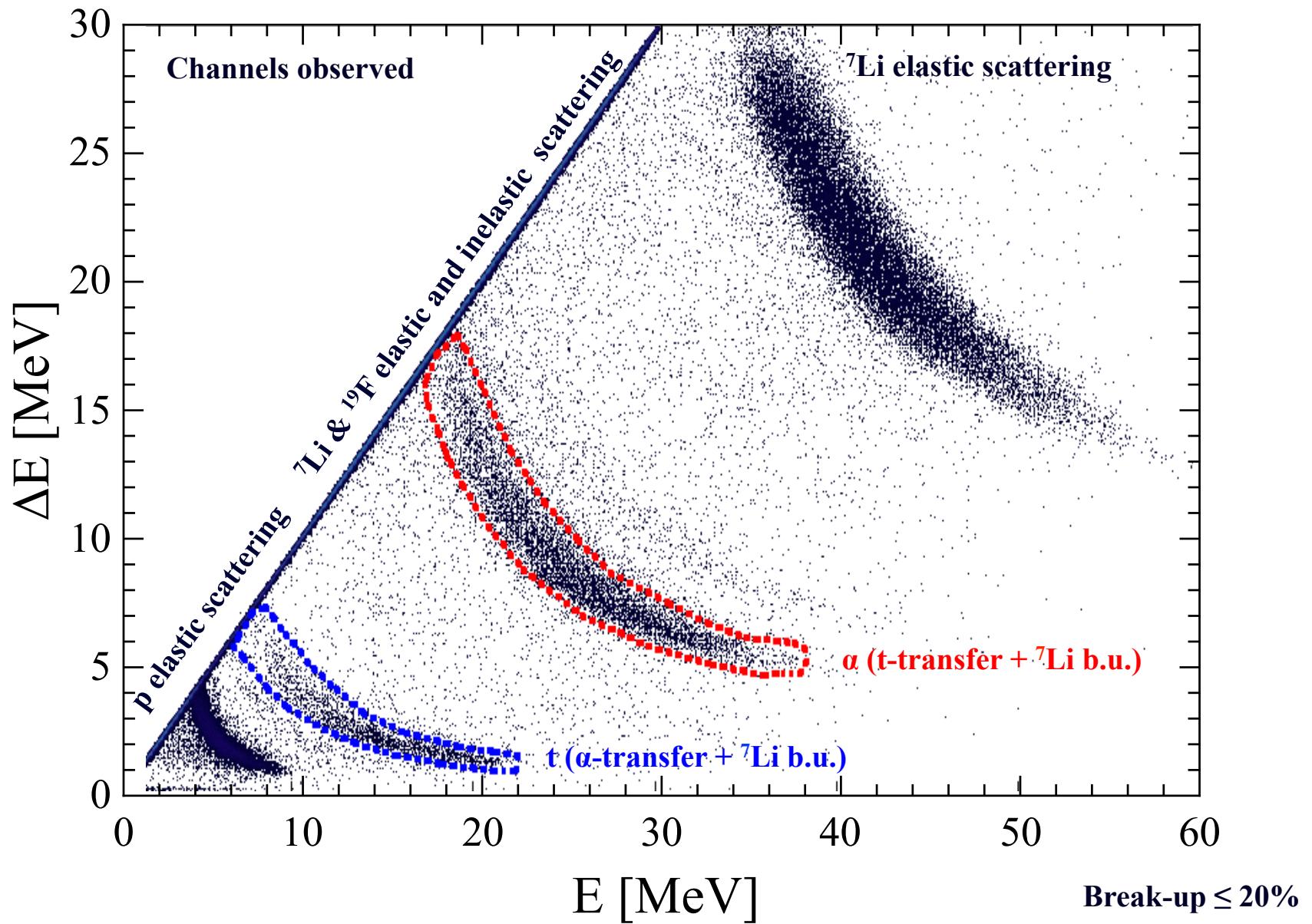
- Cluster-transfer mechanism
- Population of $A=100$ region by transfer

- Technique:

- Cluster (α or t) transfer in ${}^{98}\text{Rb}/{}^{98}\text{Sr}$
- Detection of emitted particle (t or α)
- Neutron evaporation
- Detection of γ -rays in coincidence

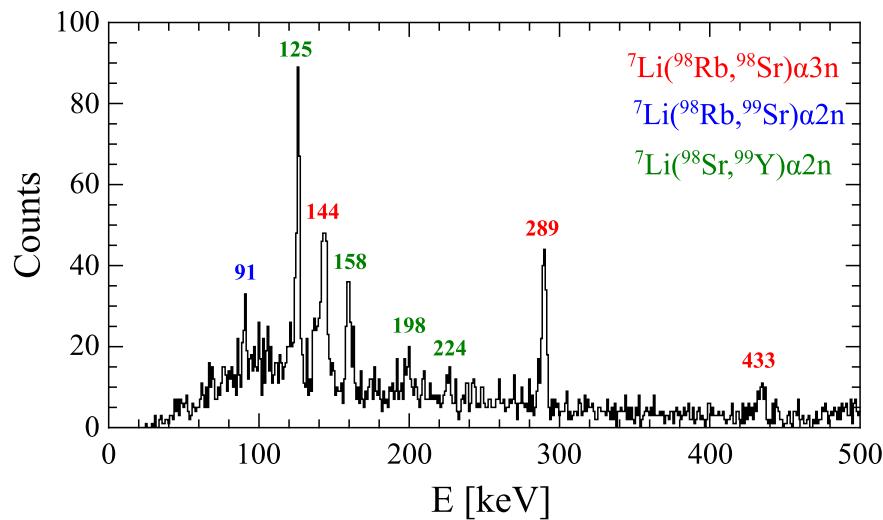
REACTIONS TOOK PLACE BOTH ON ${}^{98}\text{Rb}$ AND ${}^{98}\text{Sr}$

Particle detection

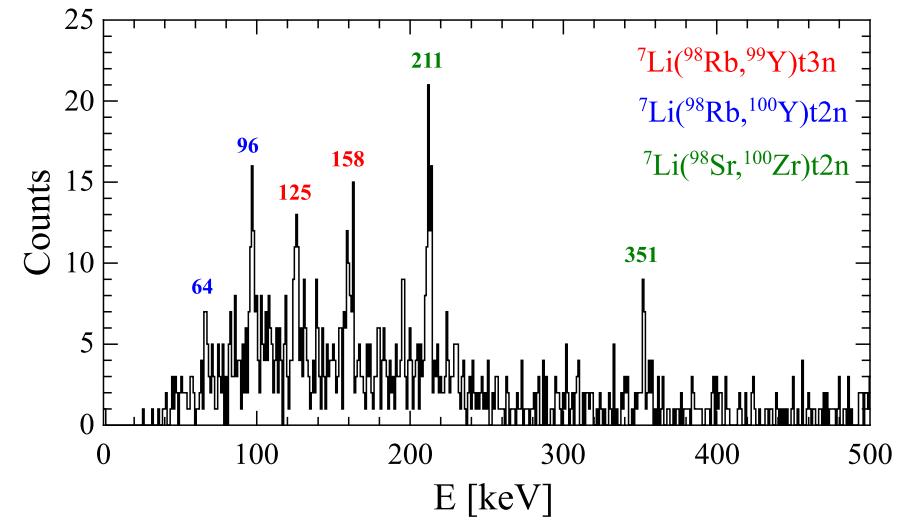


γ spectroscopy

t - transfer

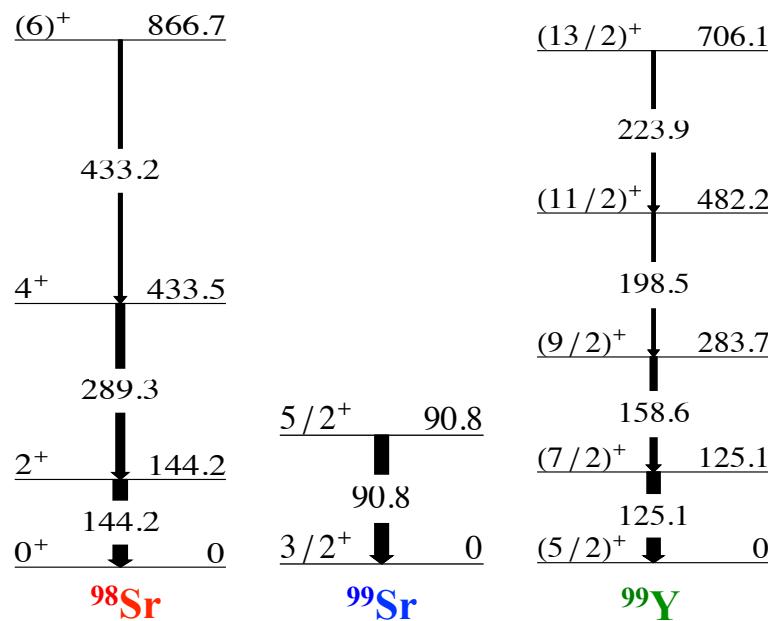
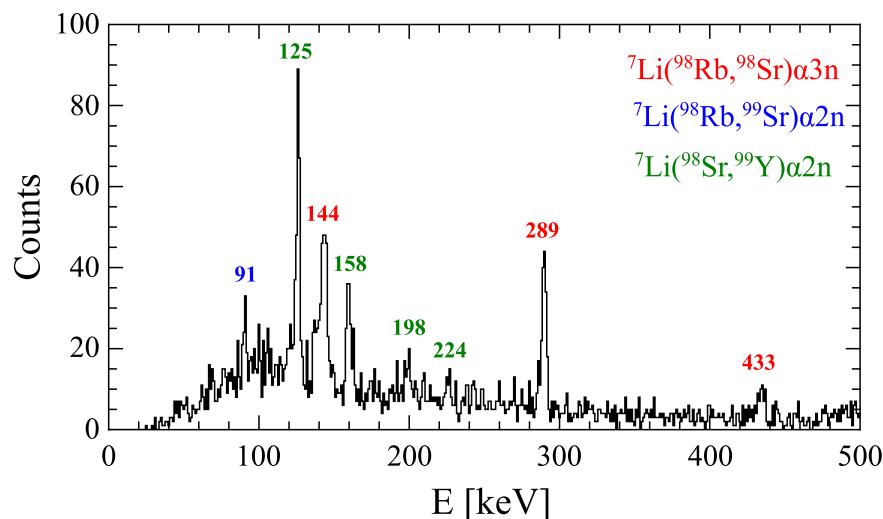


α - transfer

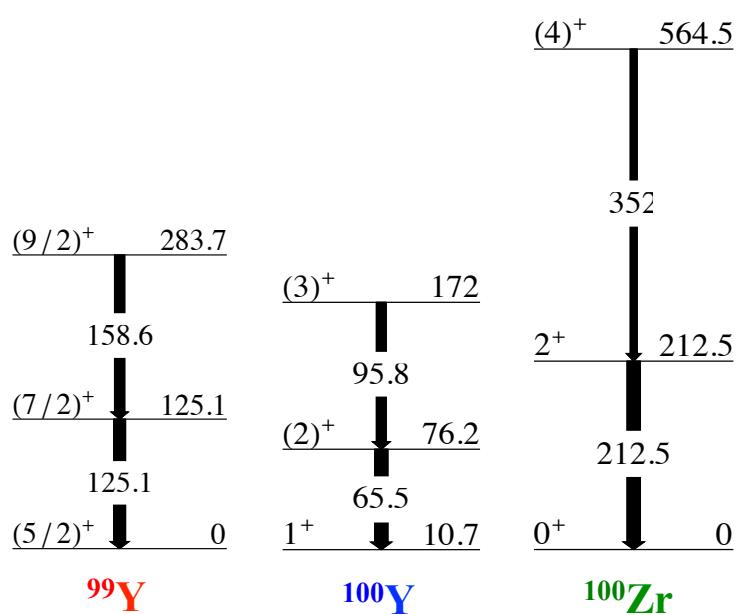
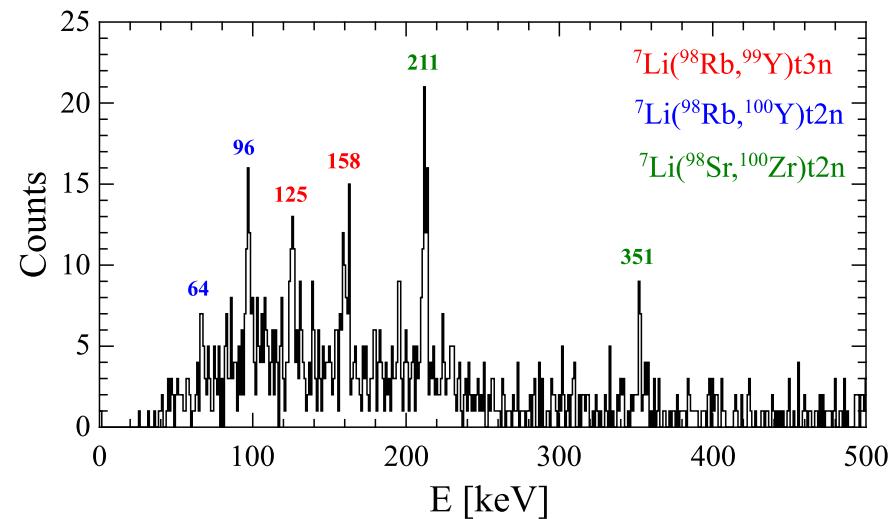


γ spectroscopy

t - transfer

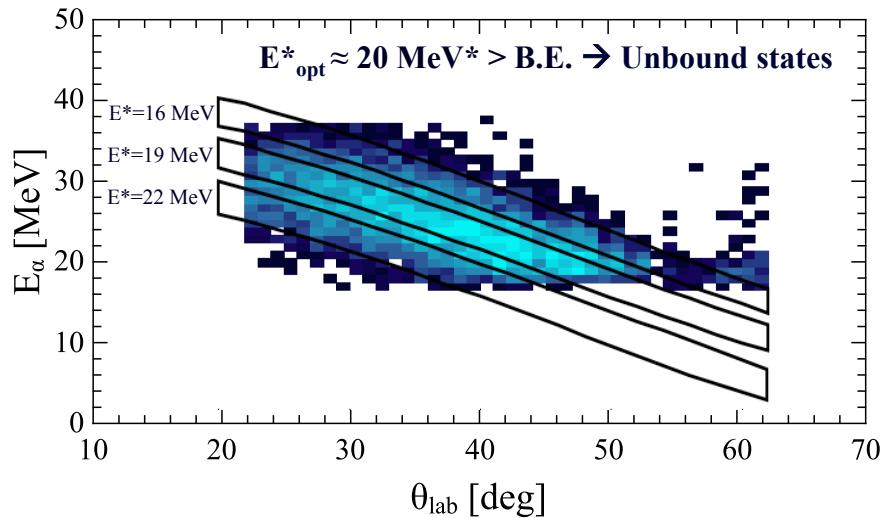


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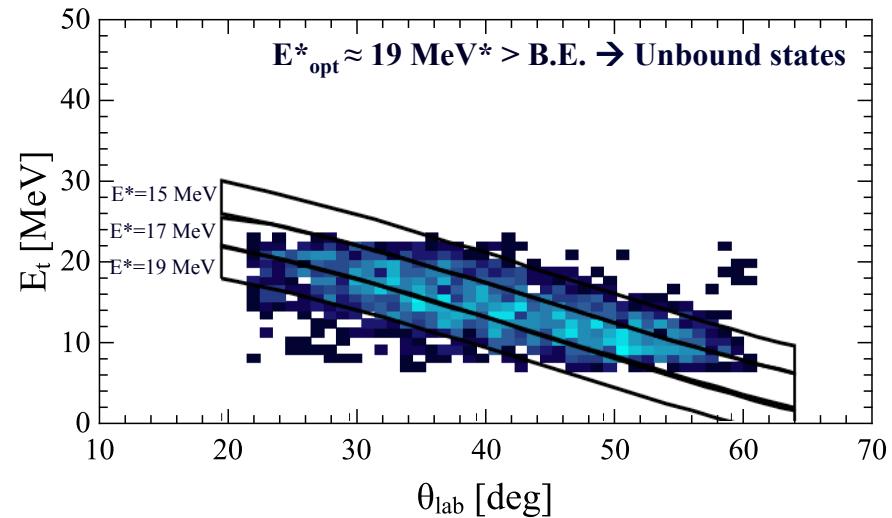


Cross Section

t - transfer



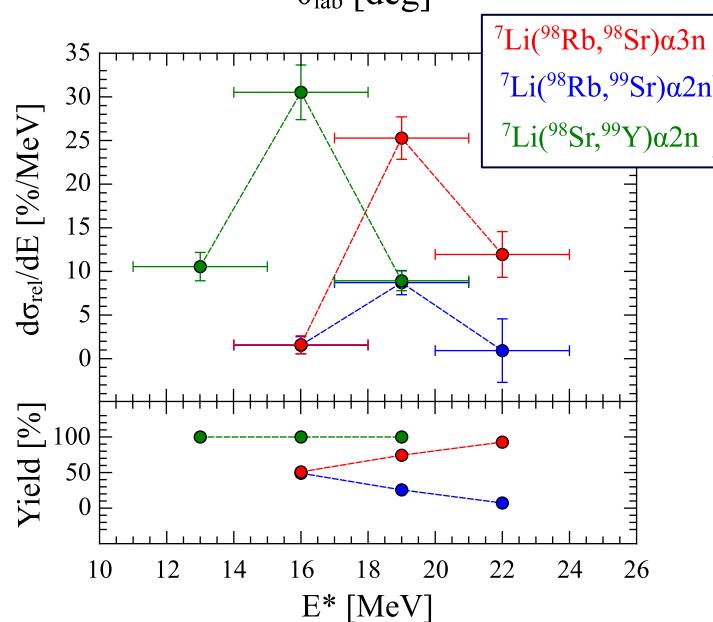
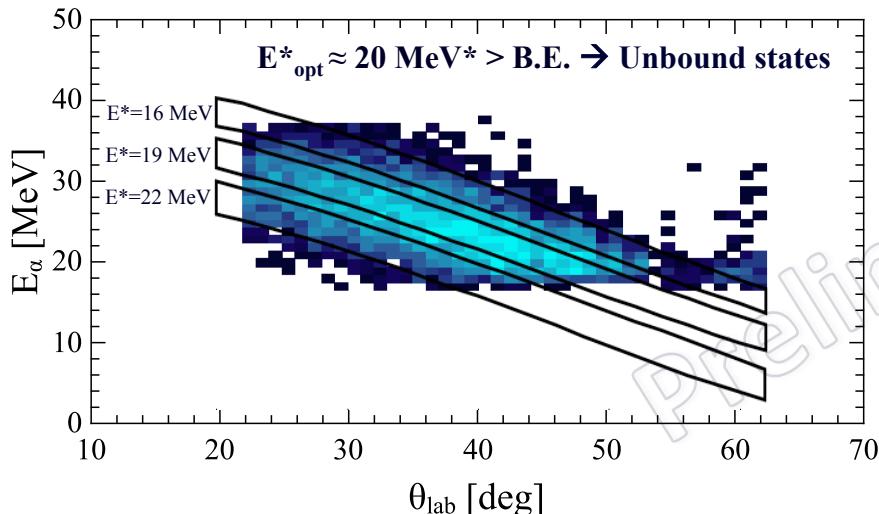
α - transfer



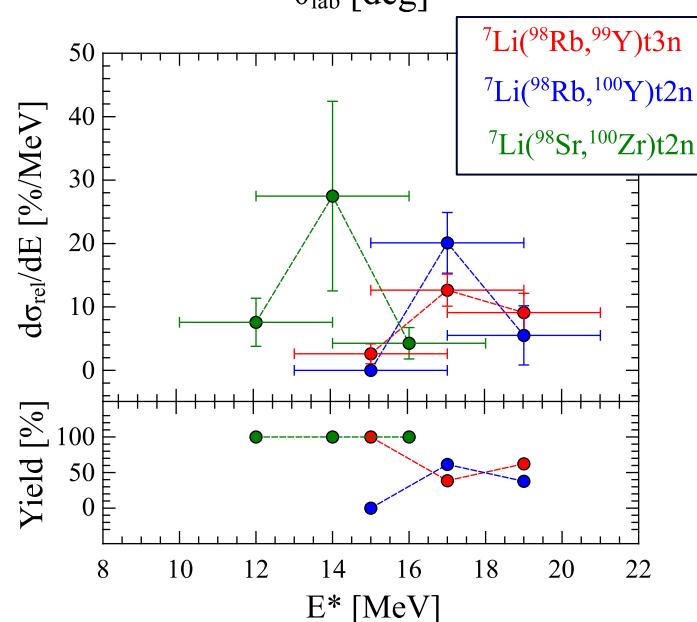
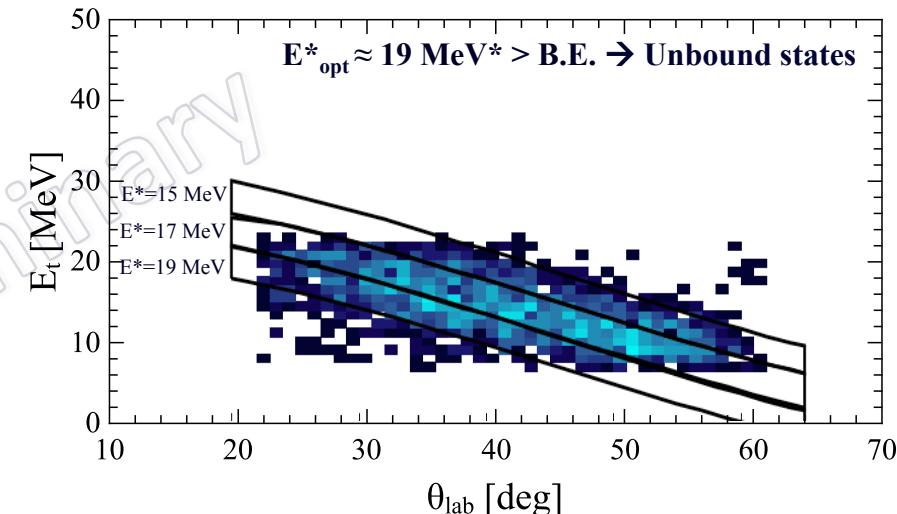
* e.g. $^{98}\text{Rb} + ^7\text{Li}$

Cross Section

t - transfer



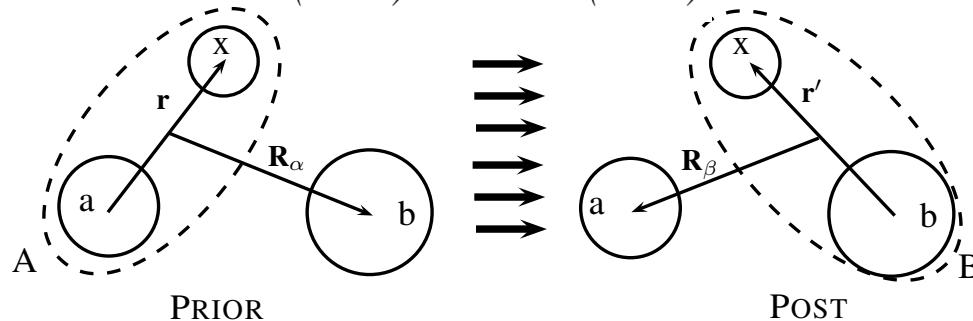
α - transfer



* e.g. $^{98}\text{Rb} + ^7\text{Li}$

Cross Section

- Transfer reaction: $(a+x)+b \rightarrow a+(b+x)$



- Total wave function:

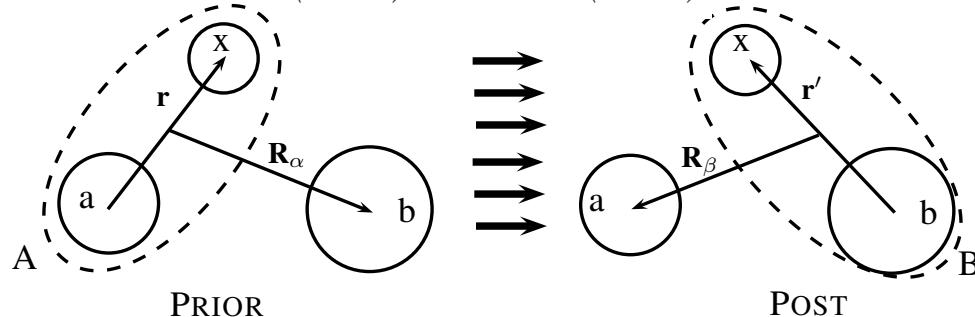
$$\psi_{tot} = \varphi_A(r)\chi_\alpha(R_\alpha) + \varphi_B(r')\chi_\beta(R_\beta)$$

- Cross section:

$$\sigma \sim \langle \varphi_B \chi_\beta | V_{int} | \varphi_A \chi_\alpha \rangle$$

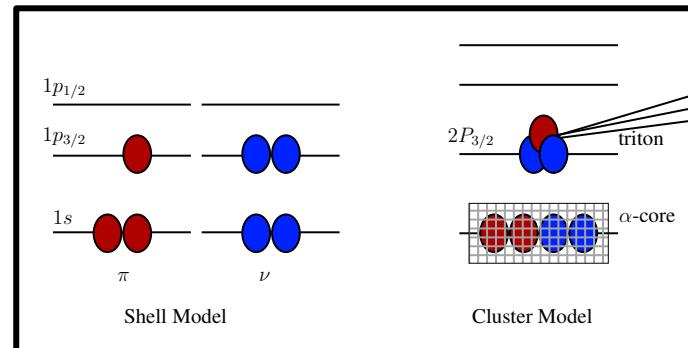
Cross Section

- Transfer reaction: $(a+x)+b \rightarrow a+(b+x)$



- Internal states:

$$\varphi_{J_{tot}M_{tot}} = \frac{u(r)}{r} \left[[Y_{l_x} \otimes \xi_{s_x}]_{j_x} \otimes \xi_{s_{core}} \right]_{J_{tot}M_{tot}}$$



Cluster model (e.g. ${}^7\text{Li}=\alpha_{\text{core}}+\text{t}$):

- Total wave function:

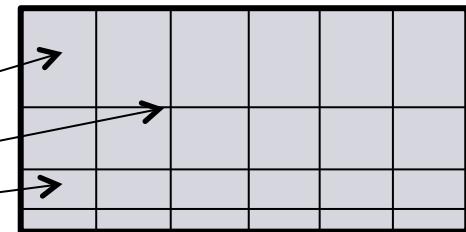
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- Cross section:

$$\sigma \sim \langle \varphi_B \chi_\beta | V_{int} | \varphi_A \chi_\alpha \rangle$$

1-step DWBA transfer from cluster states to continuum

$$V_{int}^{POST}$$

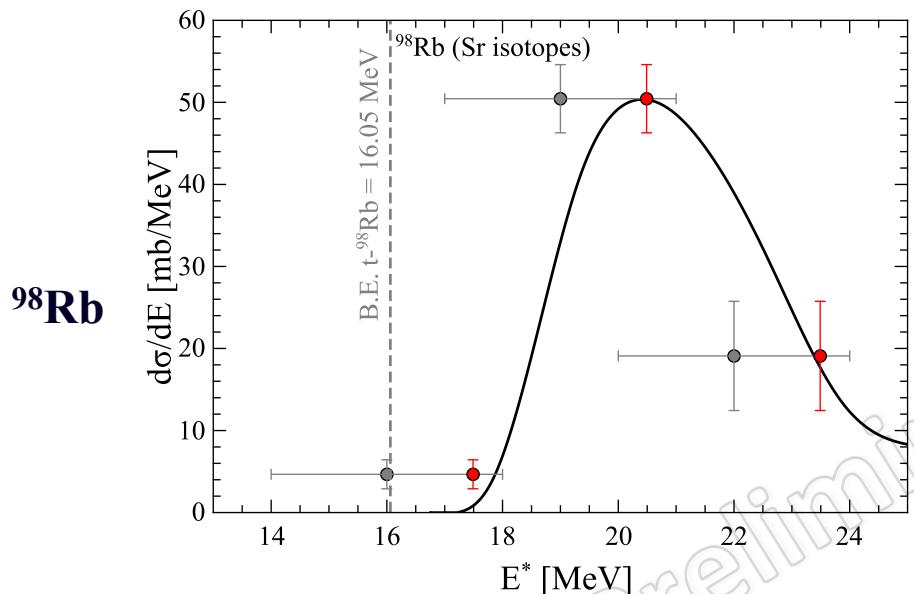


Optical parameters from elastic scattering

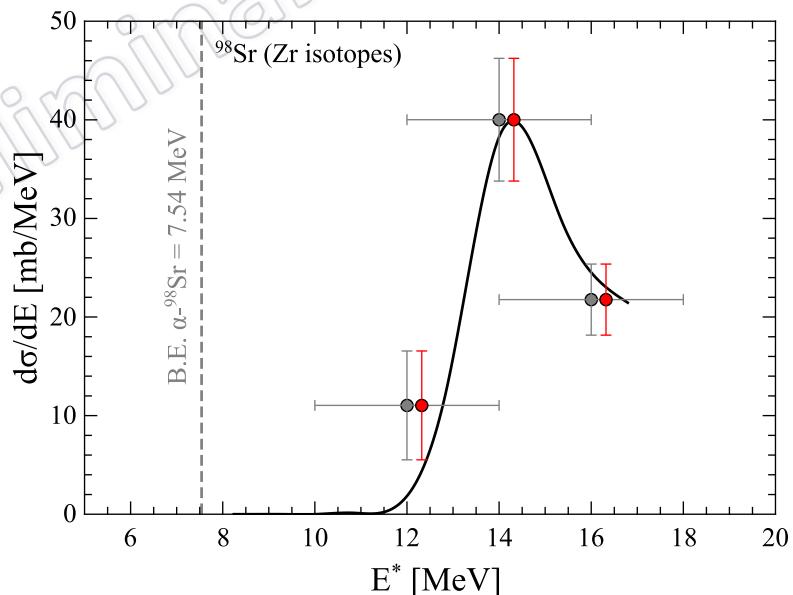
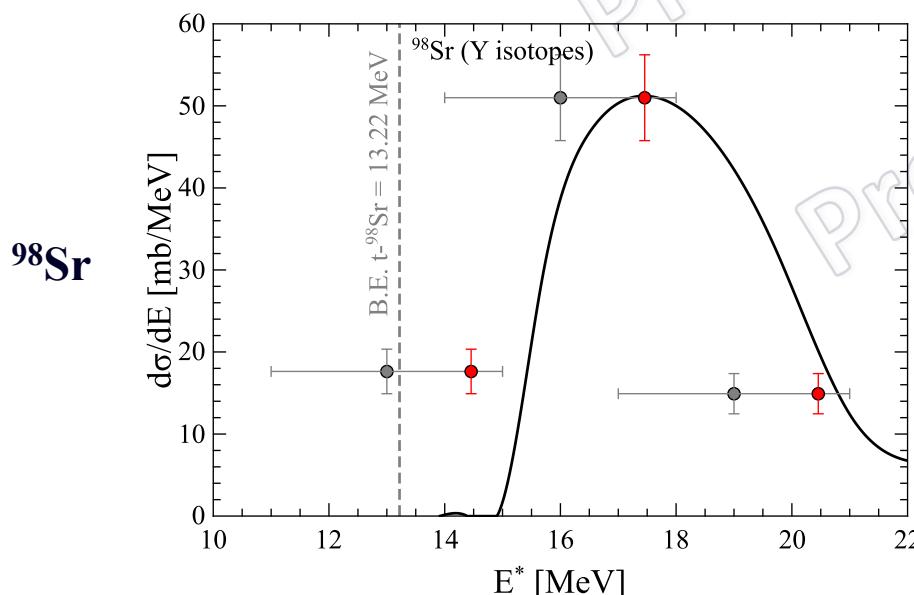
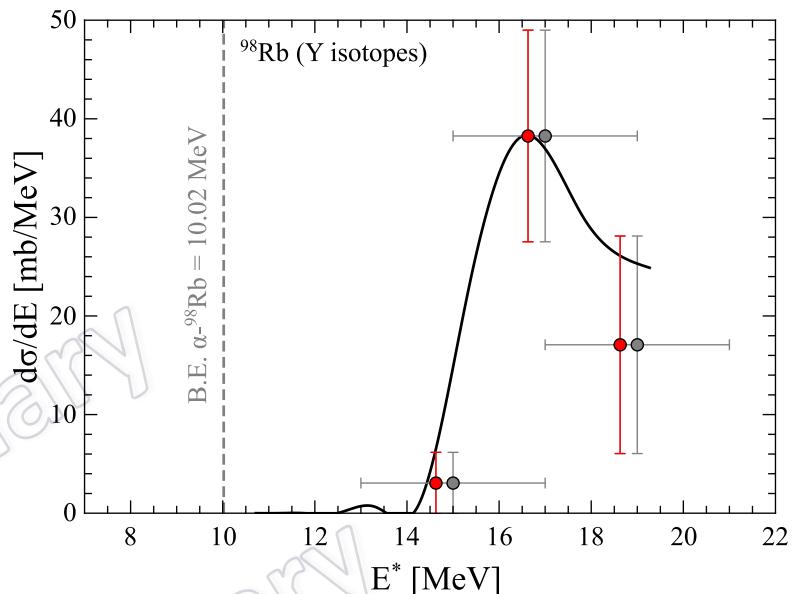
FRESCO $d\sigma/dE, d\sigma/d\Omega$

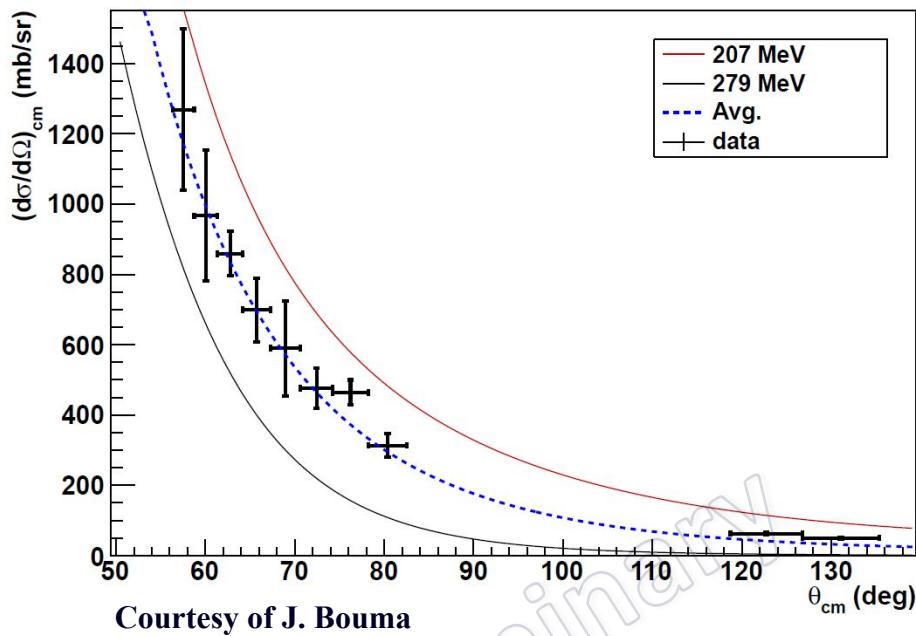
Cross Section

t - transfer

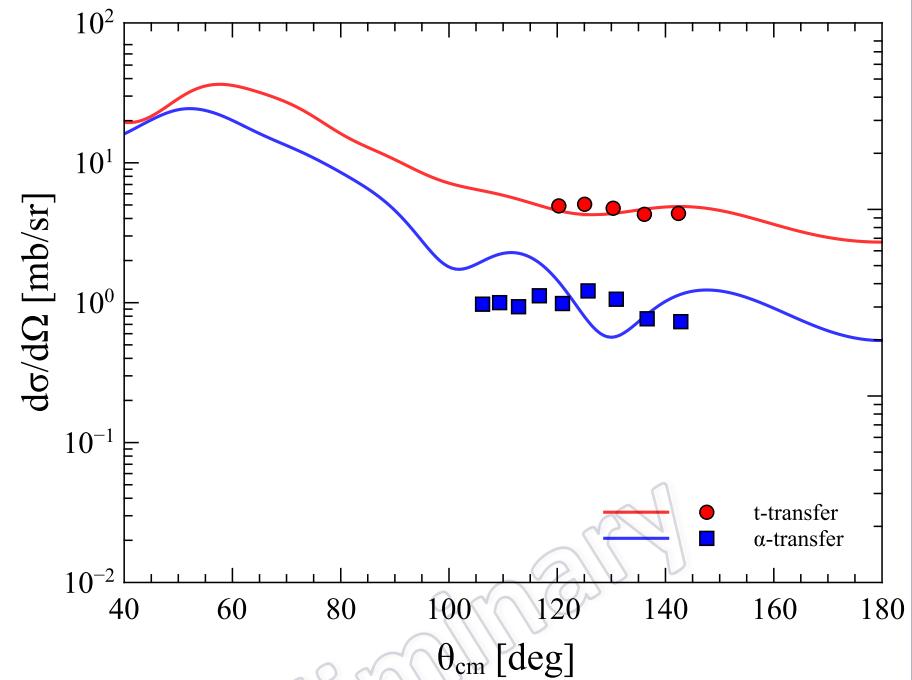


α - transfer



Elastic

Courtesy of J. Bouma

Transfer

**Excitation energy distributions and angular distributions
are qualitatively reproduced by the model**

Conclusions

- **$^{98}\text{Rb}/^{98}\text{Sr} + ^7\text{Li}$ @ 2.85 MeV/A at REX – ISOLDE using the MINIBALL – T-REX setup**

- **Analysis of particle – γ coincidence for cluster-transfer channels**

- **Difference in neutron evaporation due to different structure**

- **Spin up to $6 \hbar$ observed.**

- **Comparison of cross sections with DWBA cluster transfer to continuum**

- **Qualitative agreement with theory**



- **Use of the same mechanism in future experiments to populate neutron-rich nuclei at medium-high spin with a new generation of radioactive beams (HIE-ISOLDE, SPIRAL2, SPES etc.)**

- S. Leoni et. al, “Interplay of single-particle and collective structures in ^{46}Ca ” - $^{45}\text{K} + ^7\text{Li}$ – LoI AGATA@GANIL

- R. Orlandi, F. Flavigny et. al, “Study of 0^+ states and deformed structures in ^{48}Ca ” – $^{44}\text{Ar} + ^6\text{Li}$ – LoI AGATA@GANIL

- ...

Collaboration

S. Bottoni^{1,2,4}, S. Leoni^{1,2}, B. Fornal³, R. Raabe⁴, G. Benzoni², A. Bracco^{1,2}, F.C.L. Crespi^{1,2}, A. Morales², B. Bednarczyk³, N. Cieplika³, W. Królas³, A. Maj³, B. Szpak³, M. Callens⁴, J. Bouma⁴, J. Elseviers⁴, F. Falvigny⁴, R. Orlandi⁴, K. Rusek⁵, P. Reiter⁶, M. Seidlitz⁶, S. Klupp⁷, D. Mücher⁷, G. Georgiev⁸, D. Balabanski⁹, M. Sferrazza¹⁰, M. Kowalska¹¹, E. Rapisarda¹¹, and the MINIBALL-T-REX collaboration.

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⁶*Institut für Kernphysik der Universität zu Köln, Köln, Germany*

⁷*Physik Department, Technische Universität München, München , Germany*

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¹⁰*Université libre de Bruxelles, Bruxelles, Belgium and*

¹¹*ISOLDE, CERN, Geneve, Switzerland*

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Thank you!

