Observation of New Transuranium Isotopes in Multinucleon Transfer Reactions

Sophie Heinz

GSI Helmholtzzentrum and Justus-Liebig-Universität Gießen

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Fusion, Fragmentation and Fission

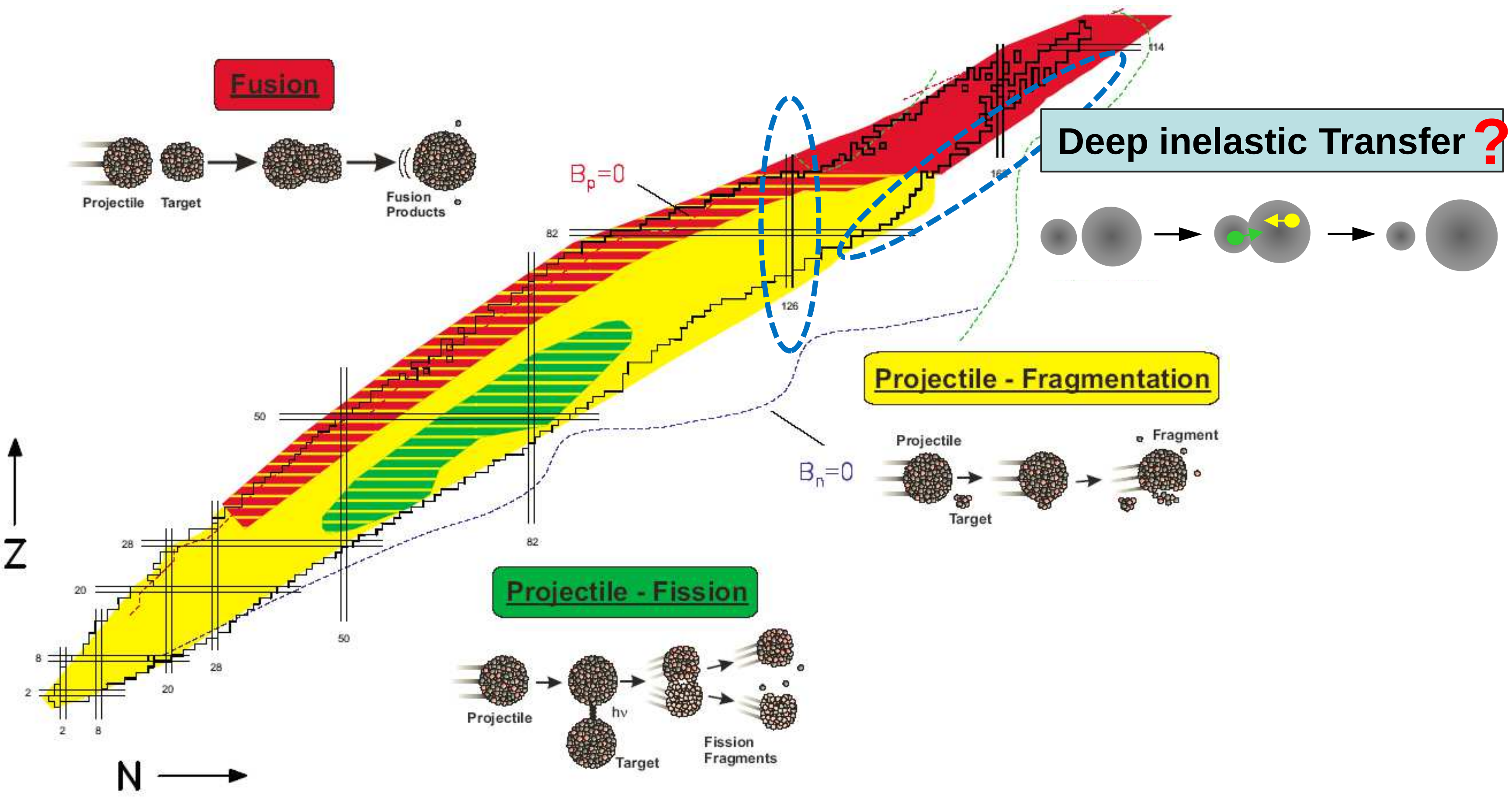
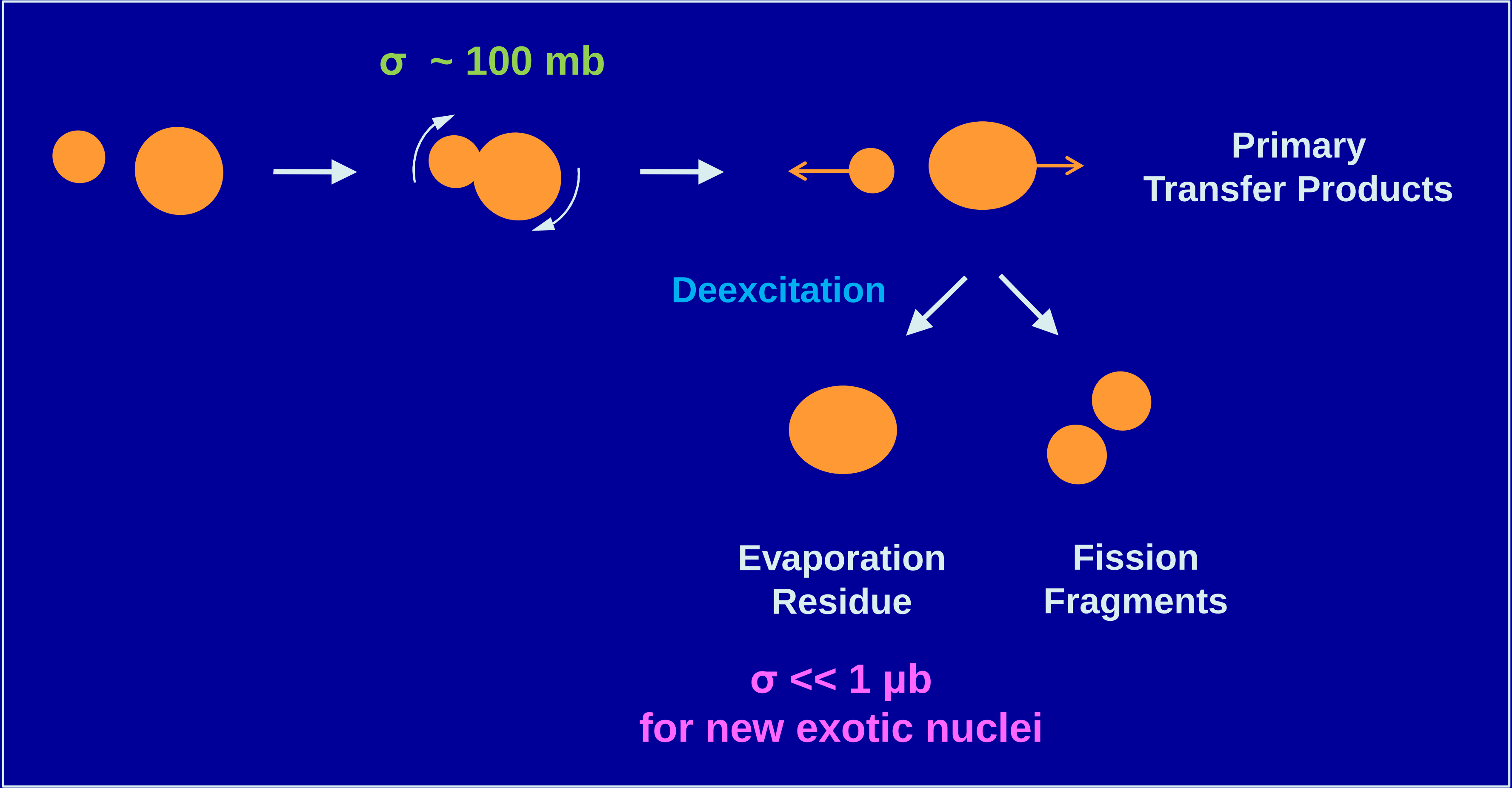


Chart: H. Geissel et al., „Exotic Nuclear Beam Facilities“, vol. 1. Wiley, 2014.

Deep Inelastic Transfer Reactions

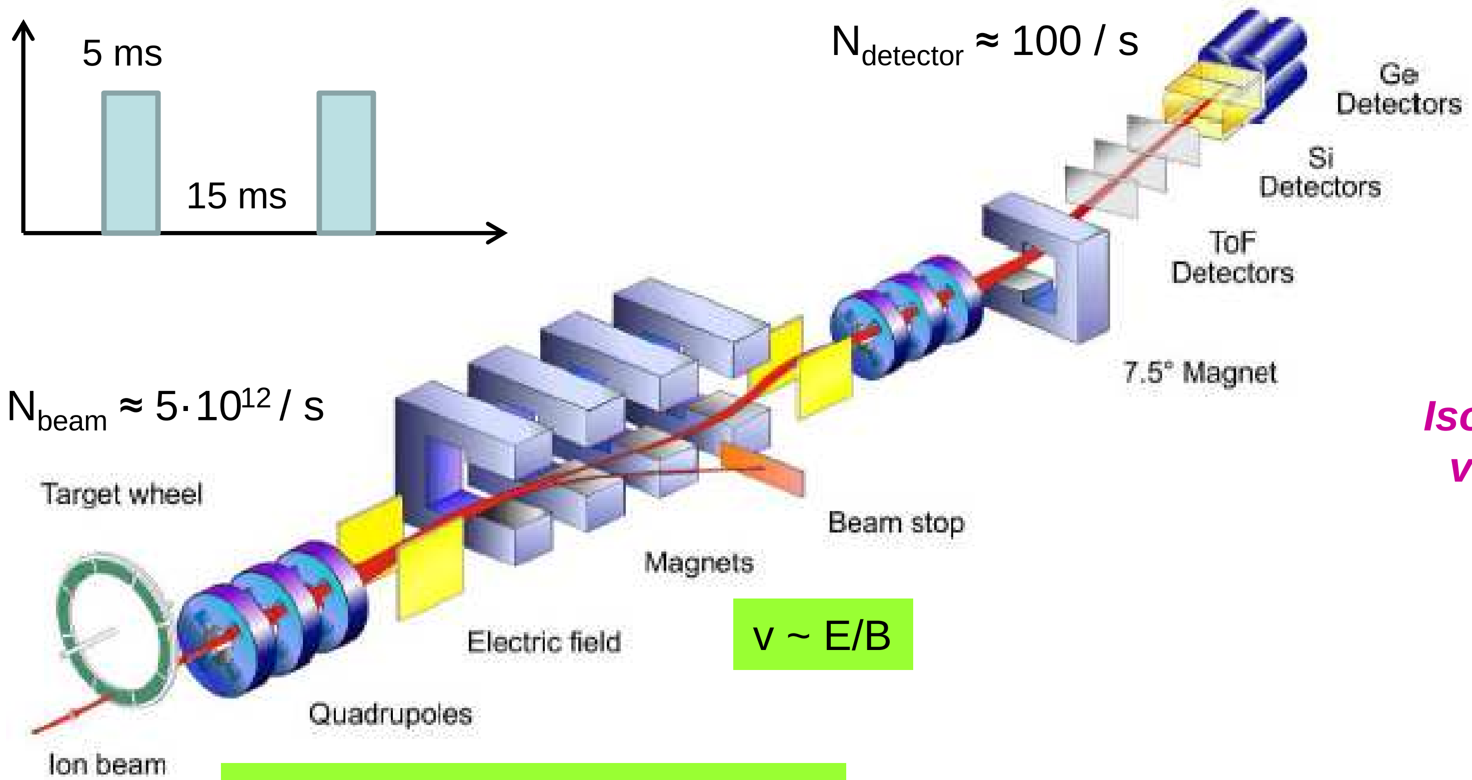


The small cross-sections require separation + single event detection

The Velocity Filter SHIP at GSI

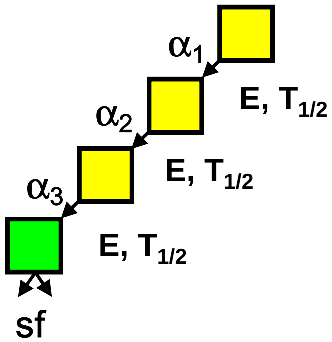
Separation and identification of heavy reaction products at SHIP

pulsed beam structure



$\Delta\Theta = (0 \pm 2)°$; $\Delta\Omega = 10$ msr

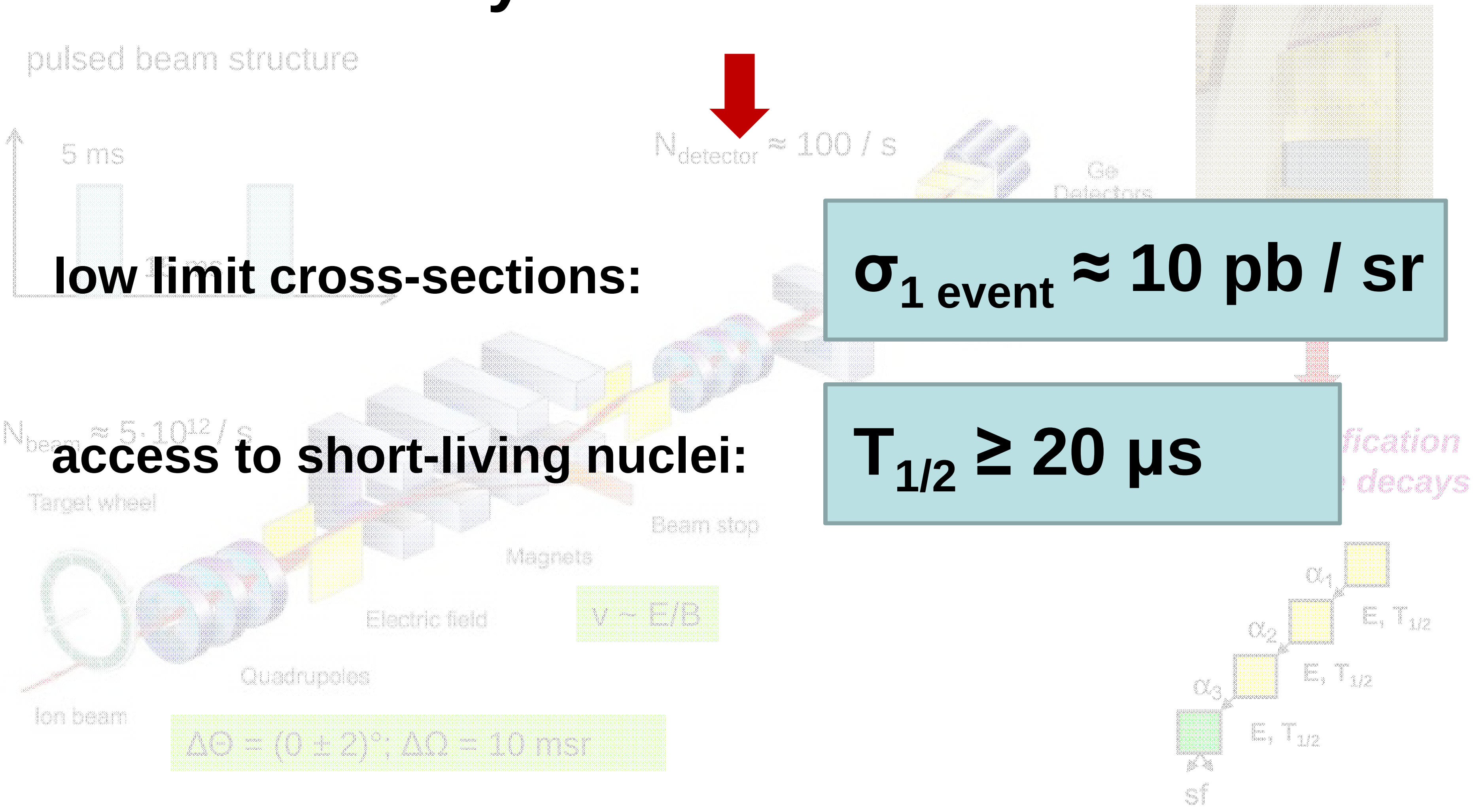
Isotope identification via α decay chains



The Velocity Filter SHIP at GSI

Separation and identification of heavy reaction products at SHIP

Very sensitive method



low limit cross-sections: $\sigma_{1\ event} \approx 10$ pb / sr

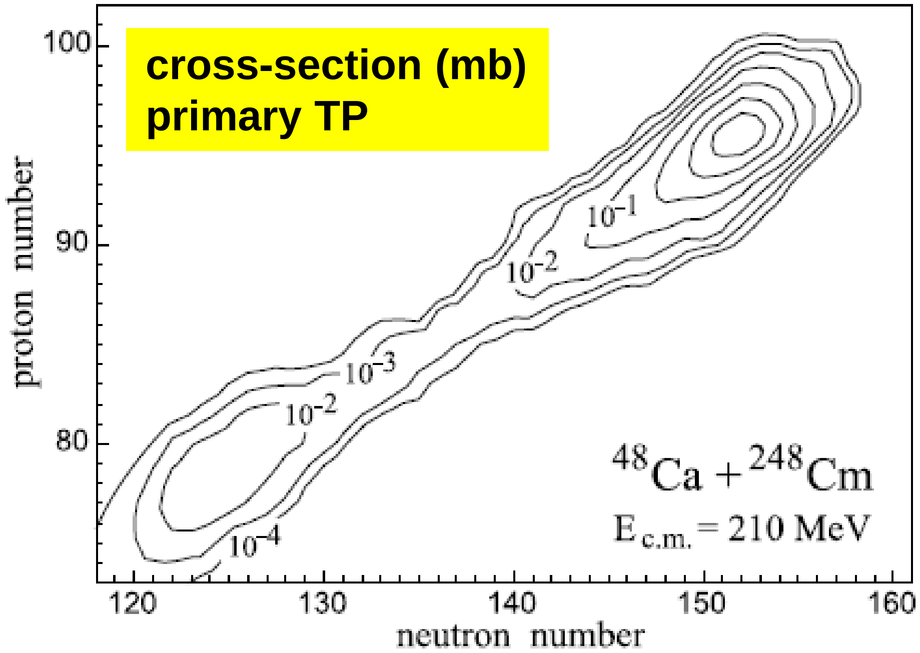
access to short-living nuclei: $T_{1/2} \geq 20$ µs

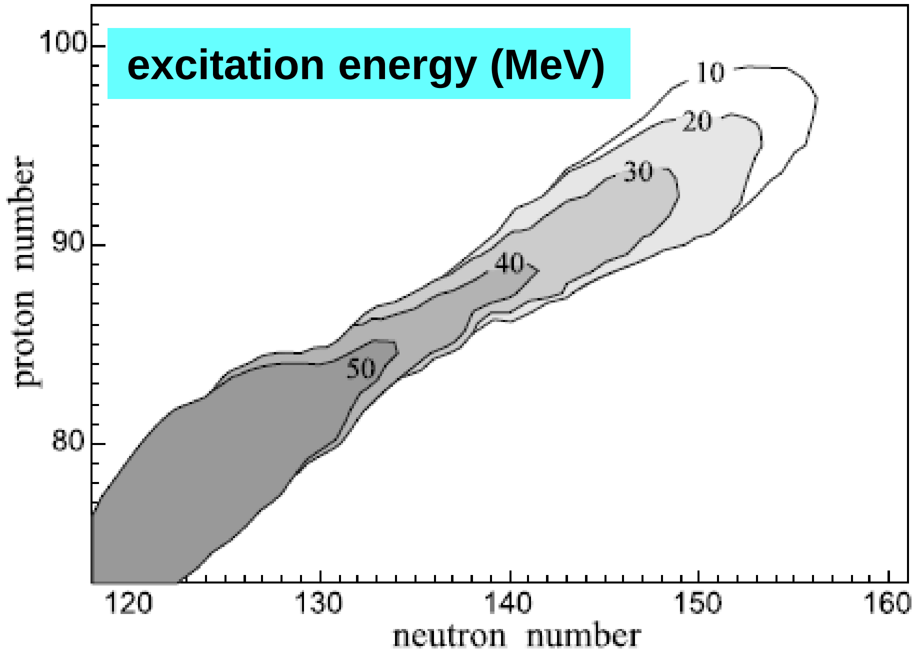
Transfer Products from $^{48}Ca + ^{248}Cm$

Theoretical model calculations for DIT in $^{48}Ca + ^{248}Cm$

→ V. Zagrebaev and W. Greiner

E_{cm} = 210 MeV (= 1.05 V_{CB})

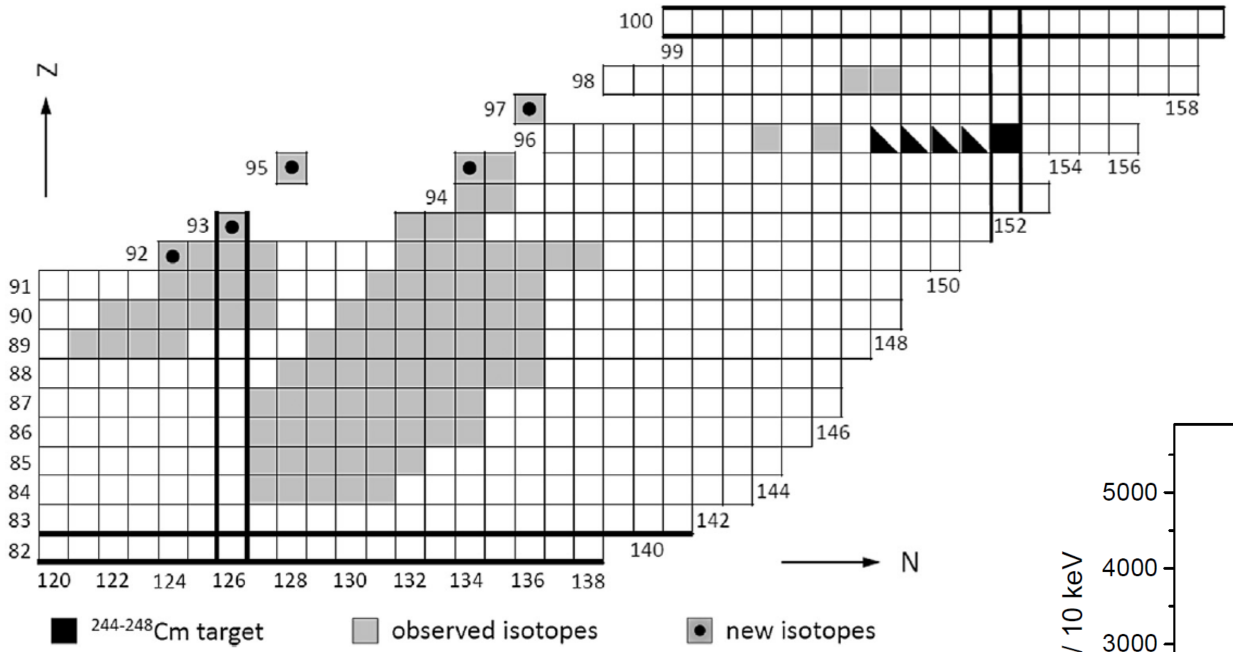


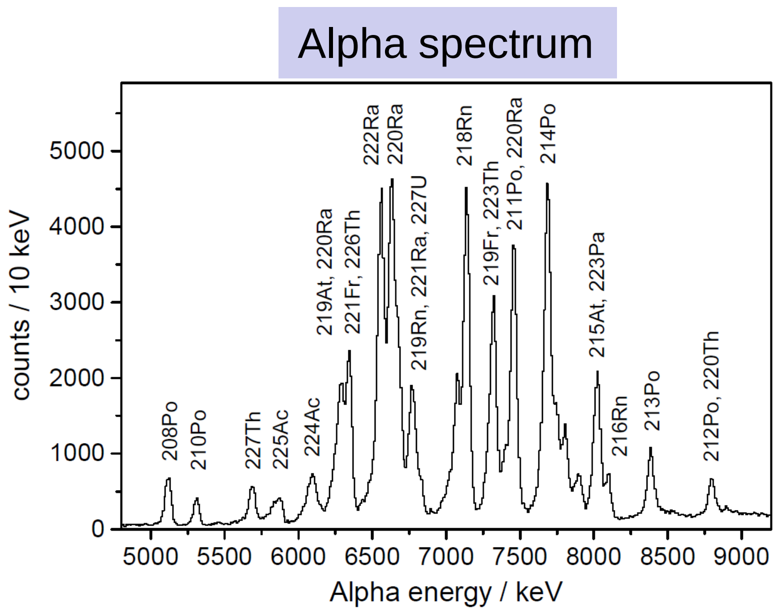


New Transuranium Isotopes Observed in DIT

Experiment at SHIP: $^{48}Ca + ^{248}Cm$, E_{cm} = 212 MeV

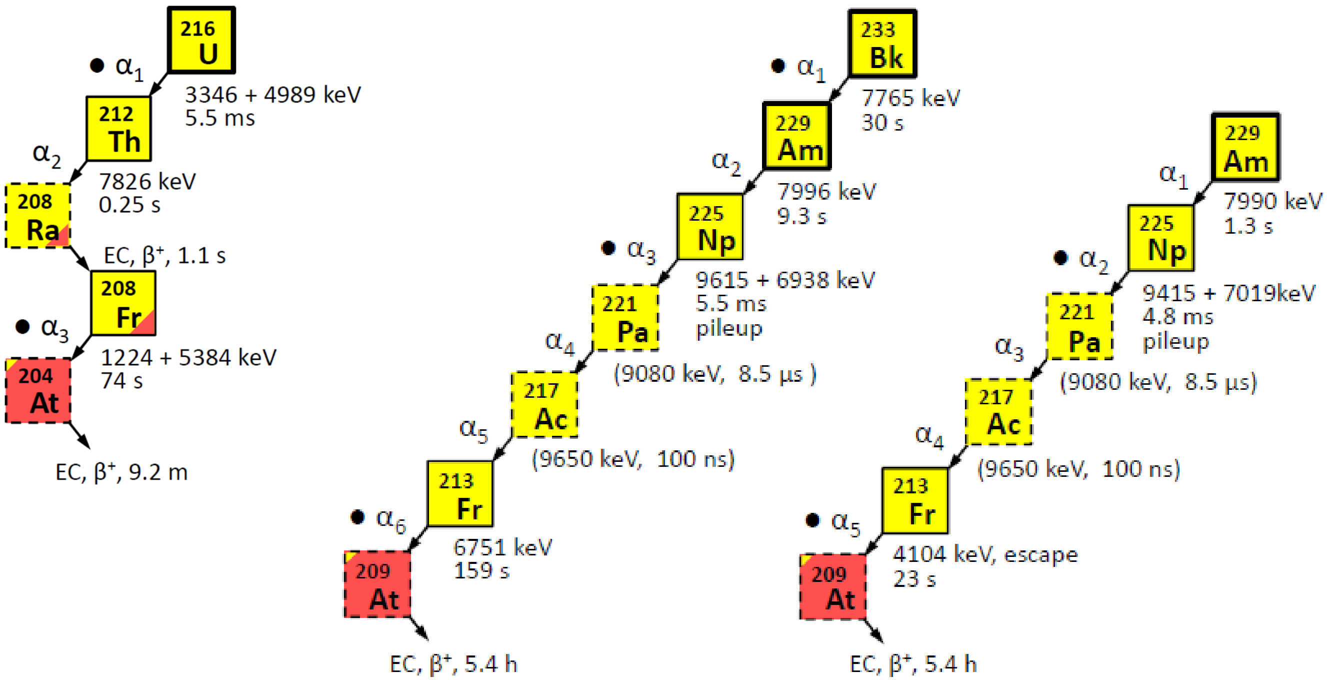
H.M. Devaraja et al., Phys. Lett. B 748, 199 (2015).

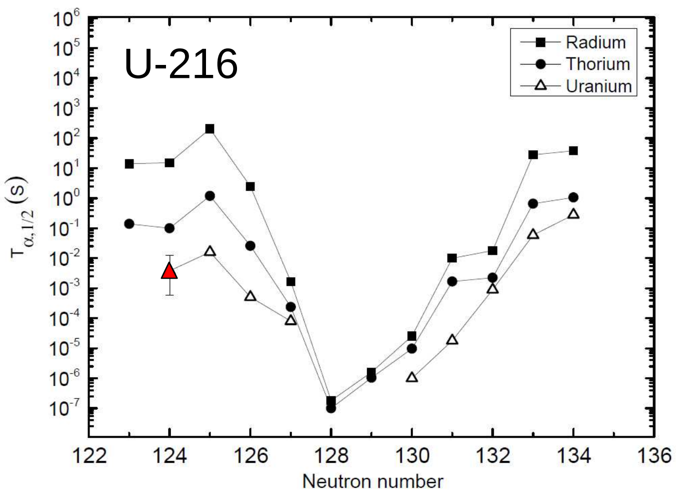


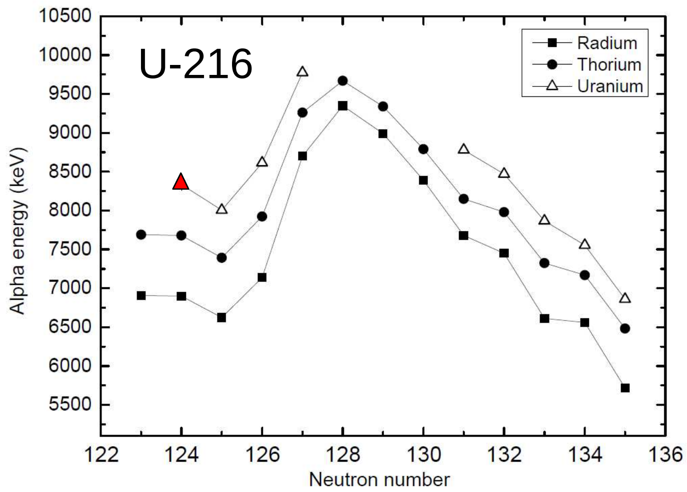


Isotope identification via α decay

Some of the New Decay Chains

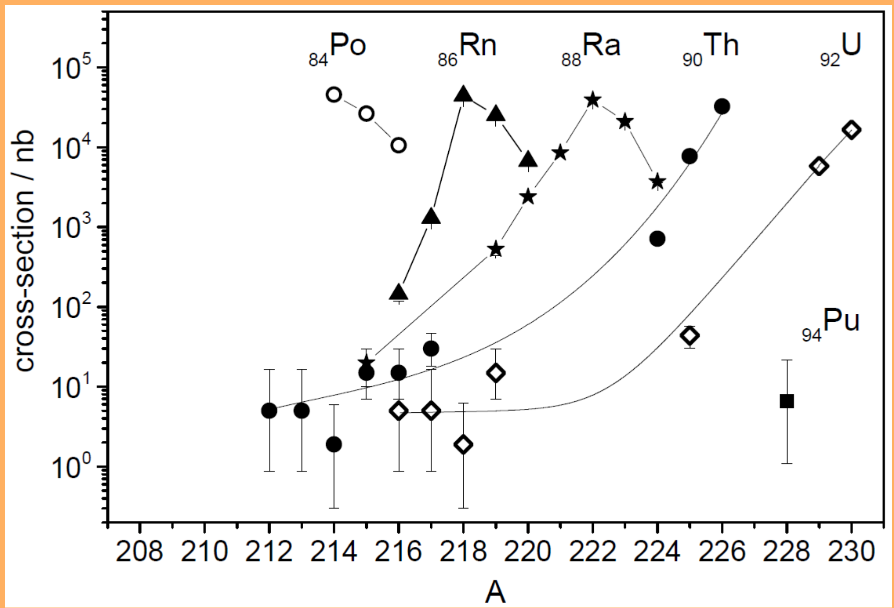




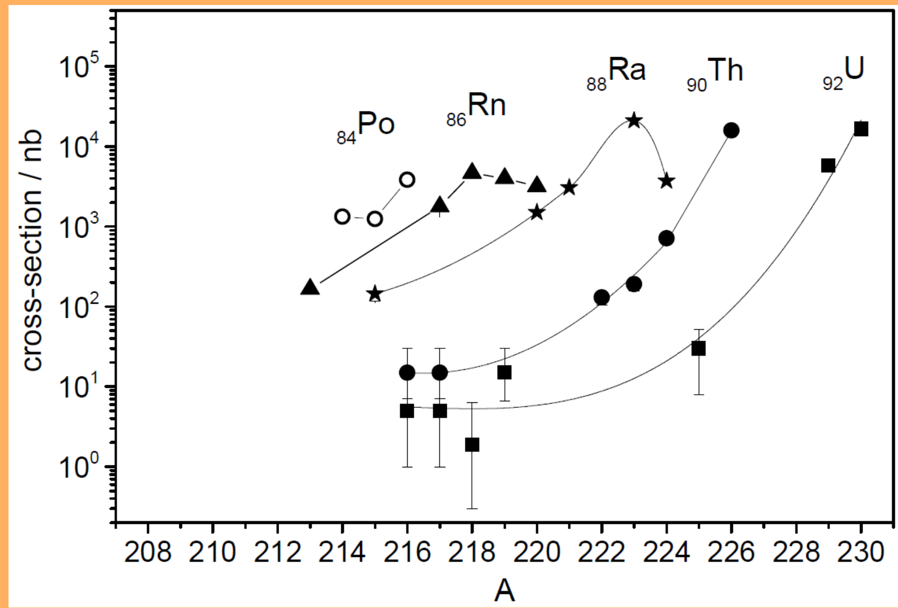


Isotopic Distributions / Cross-sections

integral yields

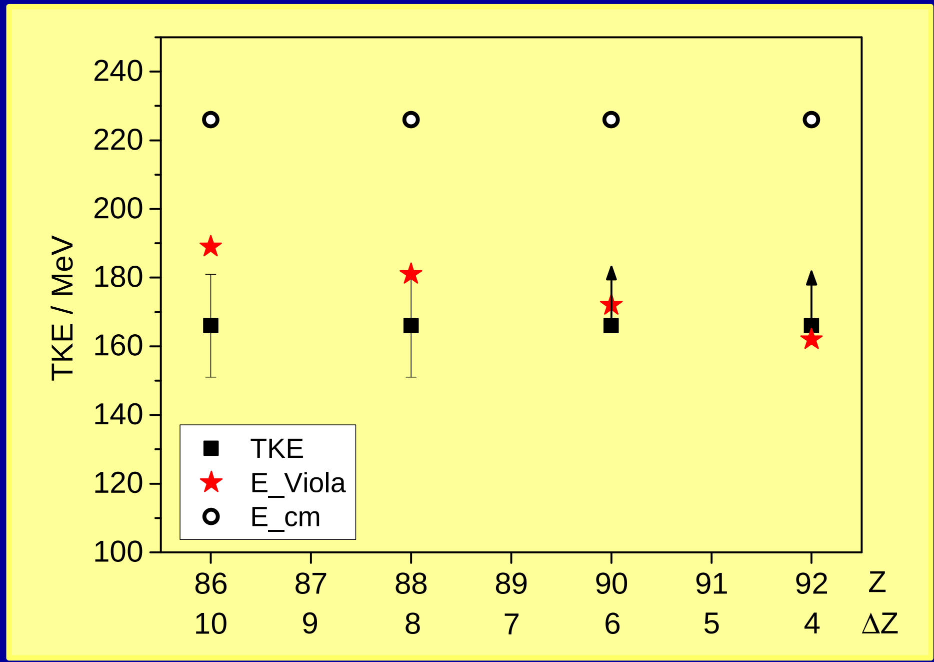


direct population



- 1-event cross-section limit: 10 pb / sr → σ_{tot} ~ 1.9 nb with ε_{SHIP} = 0.5 %
- Cross-sections up to ~50 μb were observed for DIT products → 250 events / s
- Isotopes far from the target were populated with large yields

Energy Dissipation and Excitation Energies

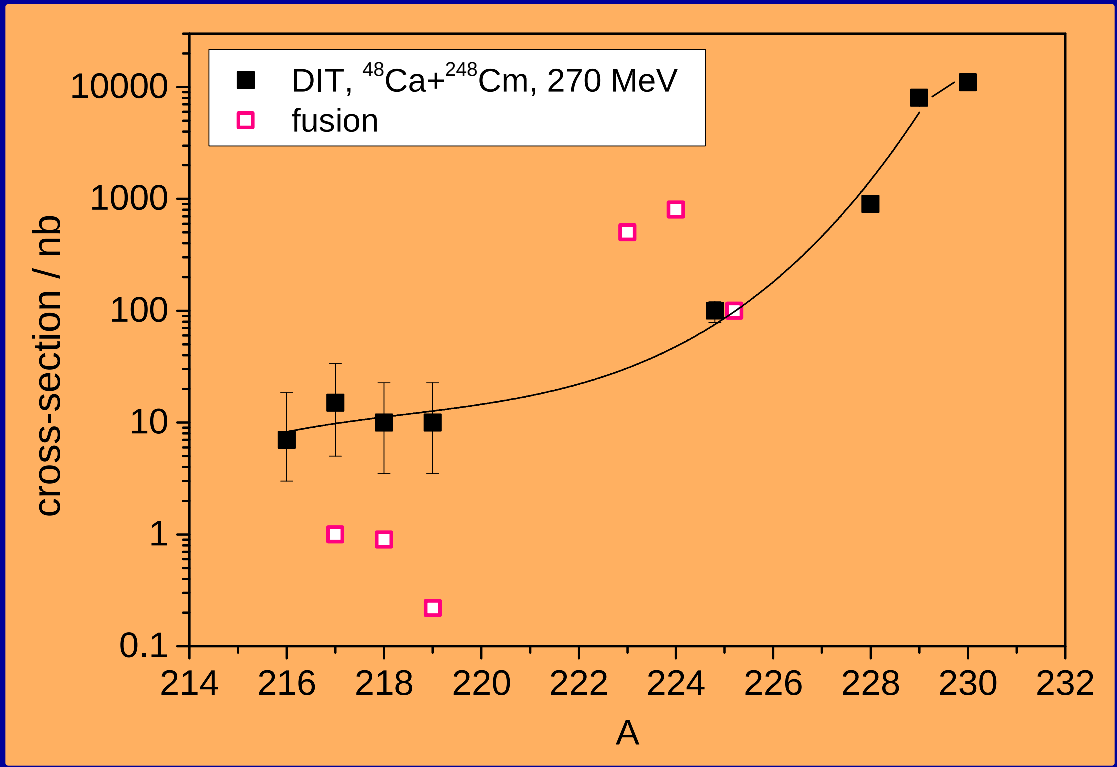


$E^* \leq E_{cm} - TKE$

- TKE: total kinetic energy → calculated from velocity of target-like DIT product
- TKE ≤ E_{viola} → reflects deep inelastic process
- E* ~ 60 MeV für Z = 86 – 92 → E* ~ 45 MeV for target-like DIT product
- Evaporation of 4 – 5 neutrons

Comparison of DIT and Fusion Reactions

→ for **uranium** isotopes



- Cross-sections similar within error bars
- DIT: population of vast region of nuclei in the same experiment
- Fusion: kinematics more favorable concerning separation criteria

Summary and Outlook

- ► DIT reactions are presently discussed as a means to produce new isotopes in the region of superheavy nuclei and N ≈ 126 nuclei

- ► In DIT reactions at SHIP we observed new transuranium nuclei
  $\rightarrow \sigma_{1\ \mathrm{event}} \sim 10$ pb / sr

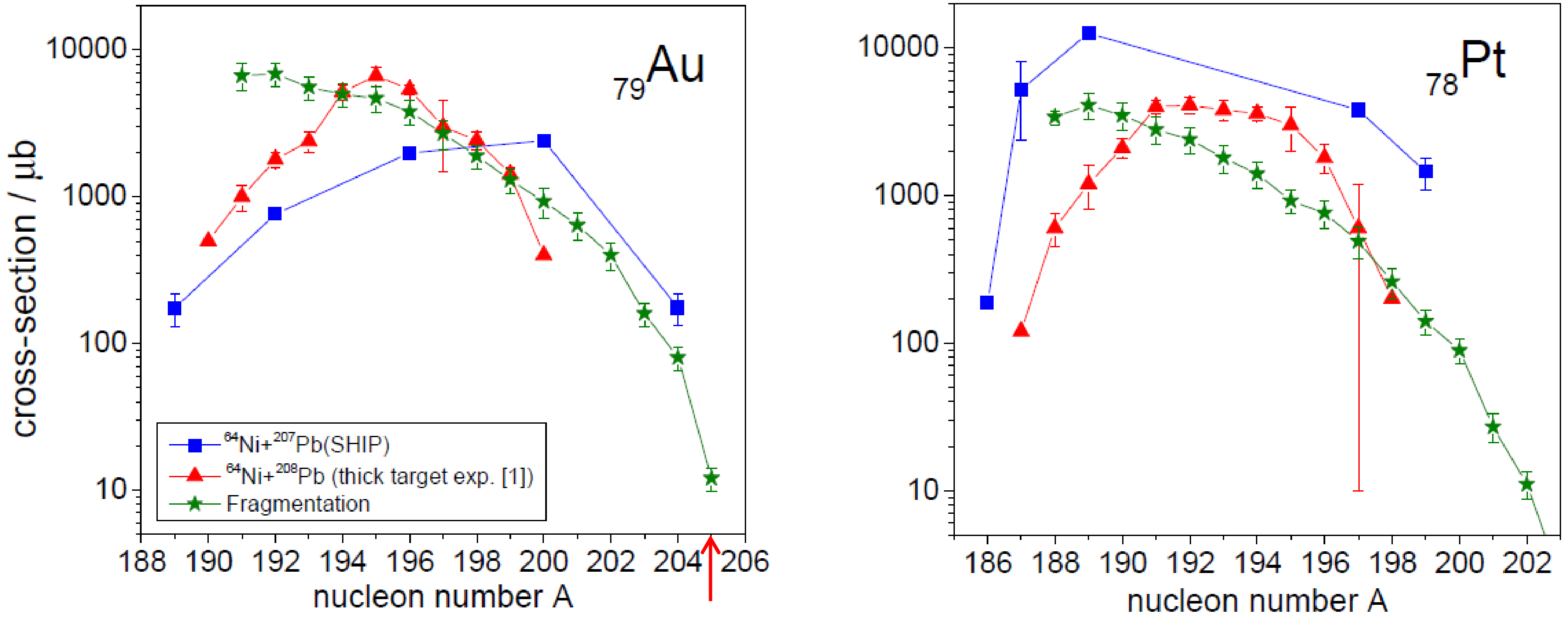
- ► In DIT reactions a vast region of nuclei can be populated in the same experiment

- ► Are DIT reactions suitable / favourable for the production of heavy nuclei?
  - Z > 92, N ≈ 126 → DIT appears favourable
  - Z < 82, N ≈ 126 → Fragmentation appears favourable
    (O. Beliuskina et al., Eur. Phys. J. A 50, 161 (2014))
  - N-rich SHN → DIT very difficult: tiny σ and missing ID methods

DIT for the N ≈ 126, Z < 82 region?

DIT in $^{64}Ni + ^{207}Pb$

Transfer and fragmentation cross-sections



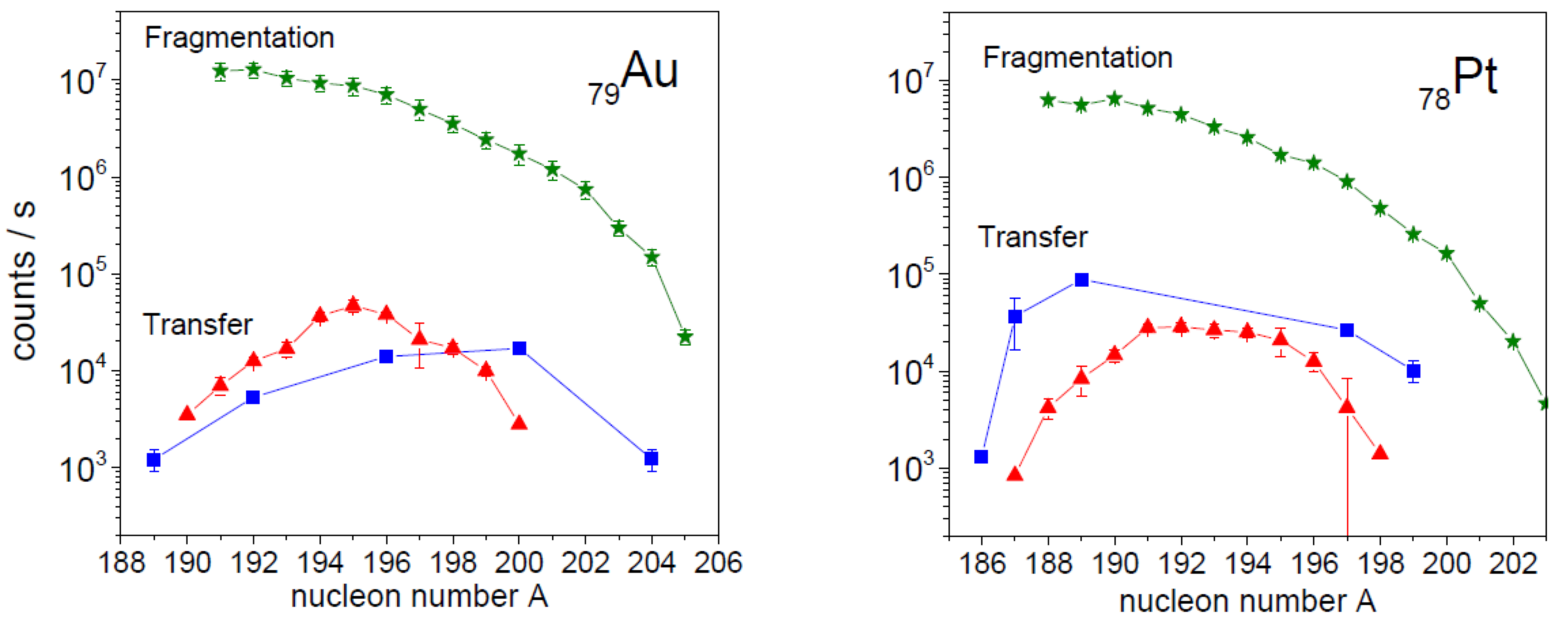
for neutron-rich nuclei: $\sigma_{Transfer} \geq \sigma_{Fragmentation}$

- *O. Beliuskina et al., Eur. Phys. J. A **50**, 161 (2014).*
- *[1] W. Krolas et al., Nucl. Phys. A **724** (2003) 289.*

DIT for the N ≈ 126, Z < 82 region?

Transfer and Fragmentation yields (at the target)

	N_{beam}	d_{Target}	efficiency
Transfer	$5 \cdot 10^{12}$ / s	500 µg / cm^2	< 5% (SHIP)
Fragmentation	$5 \cdot 10^{9}$ / s	5 g / cm^2	< 50% (FRS)



yield (Fragmentation) > 10 x yield (Transfer)