Characterizing N-Z equilibration in nuclear reaction with sub-zeptosecond resolution.

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Angular (α) distributions:

• Lifetime of PLF* correlated with rotation angle:

\[ \alpha = \cos \left( \frac{\vec{v}_{rel} \cdot \vec{v}_{CM}}{\|\vec{v}_{rel}\|\|\vec{v}_{CM}\|} \right) \]

• Angular distribution peaked for most aligned configuration. Decreases in yield with decreasing alignment.

• Excess yield largest and most strongly aligned for most asymmetric splits.

• Less aligned decays represent longer decay times.

\[ Y_T = Y_d + Y_s \]

• Dynamical yield dominates at small angles and decreases as α increases.
\[ \Delta \text{Observable} = \Delta S Y_s + \Delta d Y_d \]

- As angle of rotation increases, \( \Delta_{\text{HF}} \) (\( \Delta_{\text{LF}} \)) start off very n-poor (n-rich), then evolve towards each other.

- Exponential fit: \( a + b \ e^{-c(\alpha)} \)
  
  \( a \) = equilibrium value
  
  \( c \) = rate constant for equilibration

- First order kinetics.

- Dynamical composition generally follows the same trend as the overall composition (more extreme).
Average rate constant degree$^{-1}$:

**Symmetric systems:**
- LF $0.03 \pm 0.01$
- HF $0.02 \pm 0.01$

**Asymmetric system:**
- LF $0.02 \pm 0.01$
- HF $0.01 \pm 0.02$

- Relevant parameter to calculate the equilibration times.
- Describes how fast the equilibration occurs within the PLF$^*$.  

- Agreement of rates $\rightarrow$ force driving the equilibration is independent of the size of both partners only depends on the difference in asymmetry

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Would be very INTERESTING and NICE to do a follow up comparing our results to model calculations!
Our plan for the 3er Fragment:

Work in Progress
Velocity distributions of HF, LF and $3^{\text{er}}$F

- Dashed lines = beam velocity (i.e. 0.27c) and mid-velocity (i.e. 0.13c).

- The three of them peaked above mid-velocity (indicating that HF, LF and $3^{\text{er}}$F originate from the PLF*).

- LF produced at velocities > than mid-velocity and < than the HF. HF produced closer to beam velocity.
Thank you!

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Backup Slides
Composition vs decay alignment, for \( \alpha, \varphi \):
Angular ($\alpha$, $\varphi$ and $\Theta$) distributions: why $\alpha$?

[Cyclotron Institute, Texas A&M University]

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Composition vs decay alignment:

$$\frac{(N-Z)/A}{\text{Composition}}$$

- $^{70}\text{Zn} + ^{70}\text{Zn}$
- $^{64}\text{Zn} + ^{64}\text{Zn}$, $Z_H=12, Z_L=7$
- $^{64}\text{Ni} + ^{64}\text{Ni}$
- $^{70}\text{Zn} + ^{64}\text{Zn}$

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• We study the time-dependence of n-p equilibration in dynamically deformed nuclear systems by examining the composition of fragments produced by a system out of equilibrium.

• We employ a method to measure the equilibration's time evolution by studying the fragments emitted from the PLF* in semi-peripheral collisions at 35 MeV per nucleon as a function of the breakup alignment angle.

• The alignment angle serves efficiently as an effective clock for equilibration.

• The variation of the composition as a function of the alignment angle clock shows an exponential behavior simultaneously for both the light and the heavy fragments, suggesting first order kinetics, for all the systems studied.

• The yield and measured composition are used to extract an estimate for the purely dynamical component (unencumbered by statistical background). No modification of our extracted equilibration rate constants is warranted.

Summary:

Thank you!