Multinucleon transfer and double charge-exchange reactions

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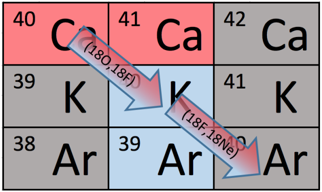
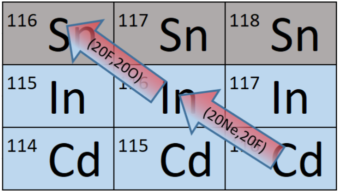
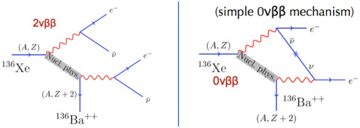
Matsue, 4th June 2018

Heavy Ion Double Charge Exchange





NUMEN @ LNS-INFN

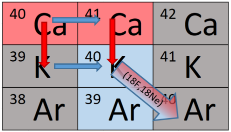


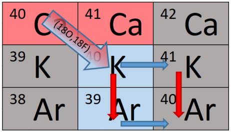
- Input for Nuclear Matrix Elements $0\nu2\beta$ decay

HIDCX @ RCNP / RIKEN

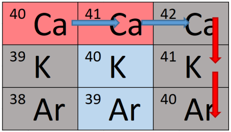
- Light targets ⇒ Drip line nuclei ($4n$, ^{9}He, ^{12}Be)
- Double GT Resonance
- GT Sum Rule

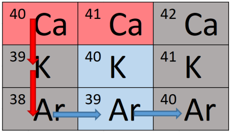
The problem

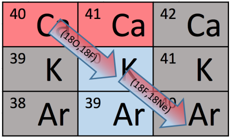


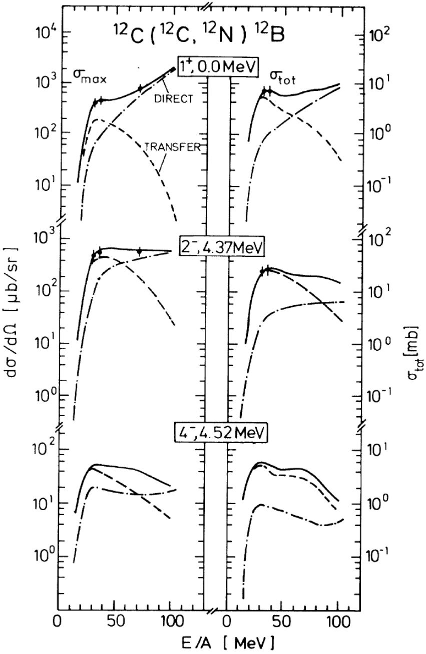


Competing Channels









Single Charge Exchange vs. Transfer

⇒ H. Lenske et al., PRL62 (1989) 1457

- E/A → 100 MeV/A (Osaka, Riken)

x Risky for states at Q_{opt}

Double CE vs. Transfer

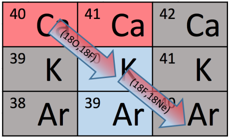
x Not much known

✓ An opportunity to exctract further information on the Wavefunction

Heavy Ions Double Charge Exchange

$(^{18}\mathrm{O},^{18}\mathrm{Ne})$; $(^{20}\mathrm{Ne},^{20}\mathrm{O})$; ... @15, 20 MeV/u
LNS-INFN Catania, Italy

Heavy Ion reactions



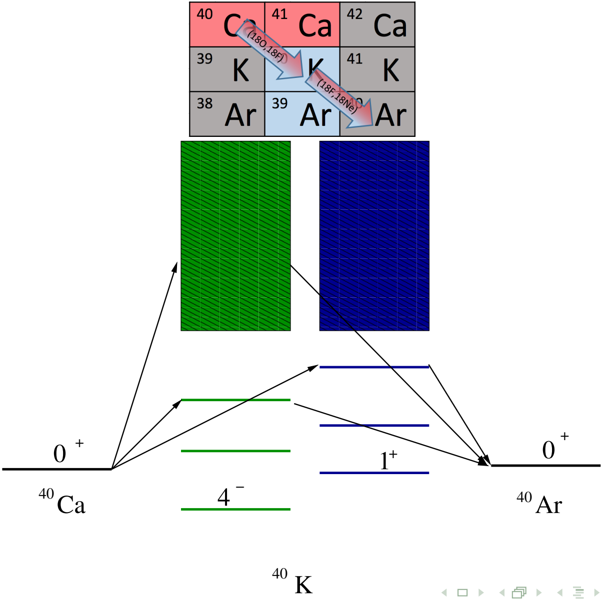
2^{nd} order DWBA

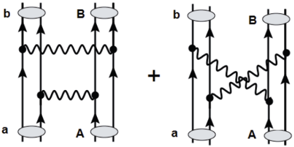
$$\sigma \propto \left| \langle \chi_\beta^- \Psi(Z \mp 2, N \pm 2) \phi(z \pm 2, n \mp 2) | VGV | \Psi(Z, N) \phi(z, n) \chi_\alpha^+ \rangle \right|^2$$

$$V = V_{ST}(\sigma_a \cdot \sigma_A)^S (\tau_a \cdot \tau_A)^T + V_T S_{12} (\tau_a \cdot \tau_A)^T$$

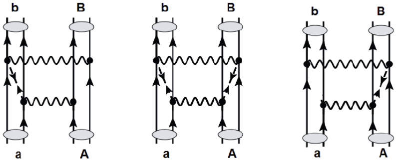
$$G = \sum |\Psi(Z \mp 1, N \pm 1) \phi(z \pm 1, n \mp 1)\rangle G(E) \langle \Psi(Z \mp 1, N \pm 1) \phi(z \pm 1, n \mp 1)|$$

Intermediate states





$2\nu\beta\beta$-"like"



$0\nu\beta\beta$-"like"

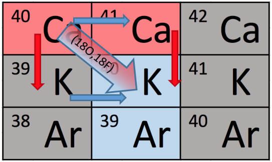
$\Rightarrow$ Work in progress by H. Lenske

Competing Channels

N^{th} order DWBA transfer

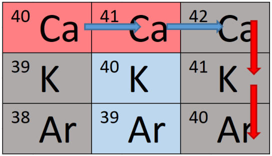
$2nd$ order

- ✓ Control over non-orthogonalities (NO)
- ✓ Prior-post avoids any NO (sim+seq)



$4th$ order

- ✗ NO to be fully implemented
- ✓ prior-post-post-post $\Rightarrow$ no problem if complete basis



Ingredients

- Optical potentials $\Rightarrow$ $t_{\rho\rho}$ folding potentials
- Overlaps $\langle ^{40}Ca|^{41}Ca\rangle$,$\langle ^{41}Ca|^{42}Ca\rangle$,$\langle ^{40}Ca|^{38}Ar\rangle$,$\langle ^{38}Ar|^{40}Ar\rangle$,...

X Sorry I am using SF $\rightarrow$ Overlap $\approx$ SF $\cdot$ s.p. Wavefunction

$\Rightarrow$ Careful with the interference between CE and transfer

For Single Charge Exchange

- QRPA calculations (HIDEX, H. Lenske)
- Love & Franey NN interaction

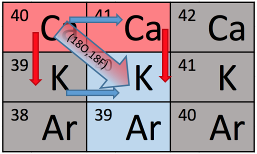
In a not so far future

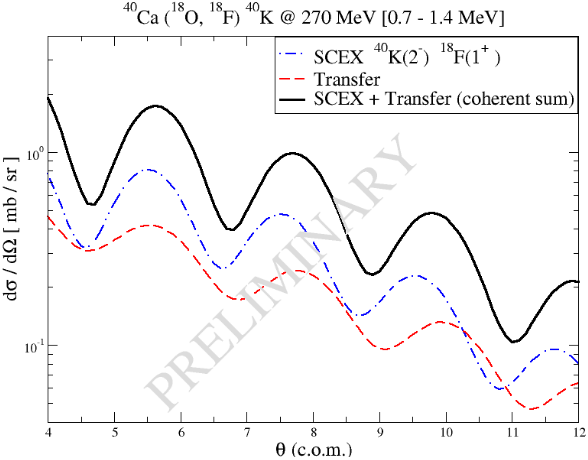
- Calculate transfer from overlaps within the same calculation

Single CE

Preliminary Results

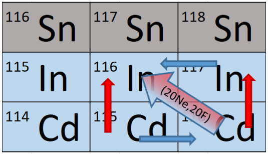
Single Charge Exchange

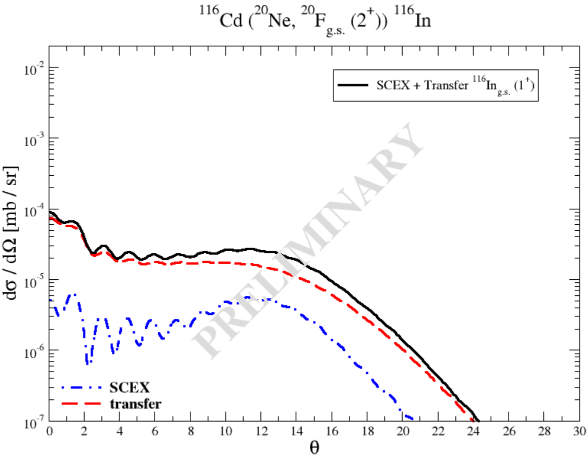




$\Rightarrow$ SF from HF+BCS input of the QRPA

Single Charge Exchange

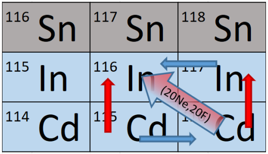


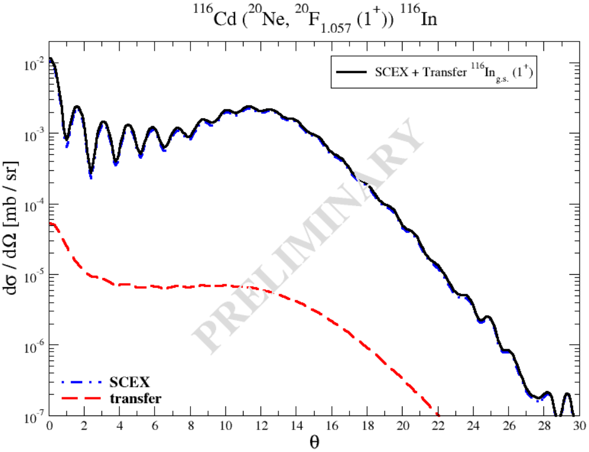


⇒ SM glekpn by J. Ferreira and J. Lubian

⇒ Also SM jj45pn and IBM2 (E. Santopinto)

Single Charge Exchange



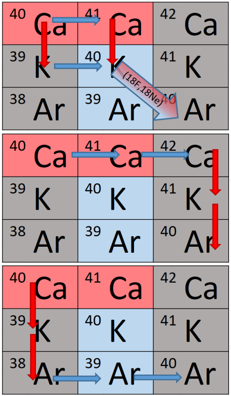


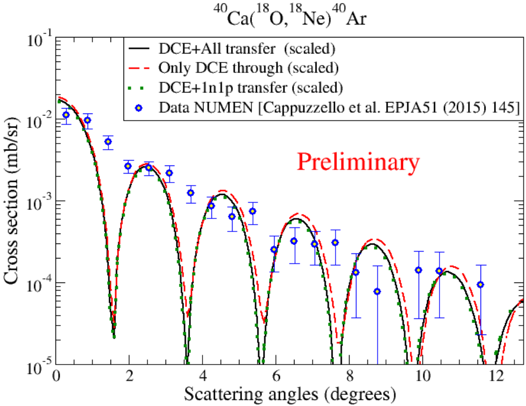
⇒ Dominance of Charge Exchange

Double CE

Preliminary Results

Double CE

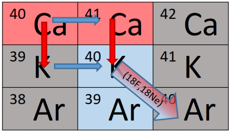


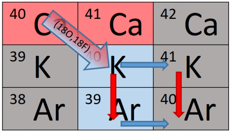


⇒ Only ground states in 2n/2p transfers

⇒ 1n1p transfer + SCE seems to be the principal competitor

✓ NO here can be under control:



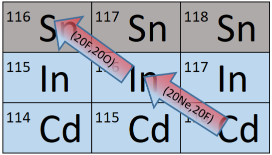


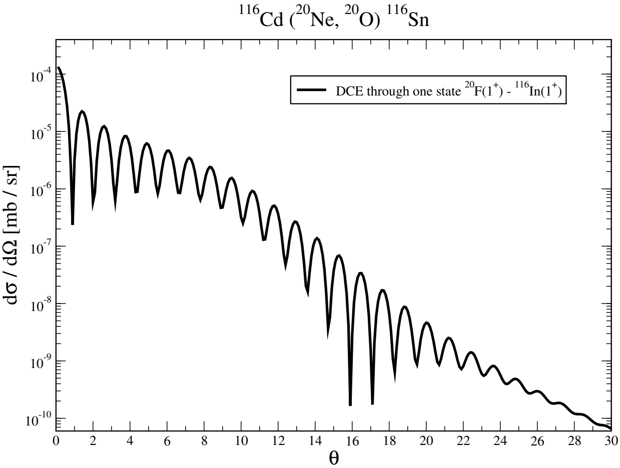
$$\mathcal{T}^{(3)}_{\text{prior,prior,SCE}} \approx (\mathcal{T}^{(2)}_{\text{seq,prior,prior}} + \mathcal{T}^{(2)}_{\text{NO,prior,prior}})\mathcal{T}_{\text{SCE}}$$

$$\mathcal{T}^{(3)}_{\text{SCE,post,post}} \approx \mathcal{T}_{SCE}(\mathcal{T}^{(2)}_{\text{seq,post,post}} + \mathcal{T}^{(2)}_{\text{NO,post,post}})$$

$$\sigma = |\sum \mathcal{T}|^2$$

Double Charge Exchange





⇒ 0.3 nb of total experimental 50 nb

⇒ Estimated 4N transfer of 10^{-5} nb (J. Ferreira and J. Lubian)

Conclusions

Conclusions

- Lot of work to be done
- Transfer is a small “contaminant”
  - Optimum Q-value
  - Larger order

✓ Experimentally also 2n/2p transfer channels can provide further information

✓ NO for the main contribution (1n1p transfer) are under control

$\Rightarrow$ Careful with sign conventions

?? Other contributions: deformation

Thank you!!

Also thanks to the whole NUMEN Collaboration

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NUMEN

E. Aciksoz, L. Acosta, C. Agodi, X. Aslanouglou, N. Auerbach, J. I. Bellone, R. Bijker, S. Bianco, D. Bonanno, D. Bongiovanni, T. Borello, I. Boztosun, V. Branchina, S. Burrello, M.P. Bussa, L. Busso, S. Calabrese, L. Calabretta, A. Calanna, D. Calvo, F. Cappuzzello, D. Carbone, M. Cavallaro, E.R. Chávez Lomelí, M. Colonna, G. D'Agostino, N. Deshmuk, P.N. de Faria, C. Ferraresi, J.L. Ferreira, P. Finocchiaro, A. Foti, G. Gallo, U. Garcia, G. Giraudo, V. Greco, A. Hacisalihoglu, J. Kotila, F. Iazzi, R. Introzzi, G. Lanzalone, A. Lavagno, F. La Via, J.A. Lay, H. Lenske, R. Linares, G. Litrico, F. Longhitano, D. Lo Presti, J. Lubian, N. Medina, D. R. Mendes, A. Muoio, J. R. B. Oliveira, A. Pakou, L. Pandola, H. Petrascu, F. Pinna, F. Pirri, S. Reito, D. Rifuggiato, M.R.D. Rodrigues, A. Russo, G. Russo, G. Santagati, E. Santopinto, O. Sgouros, S.O. Solakcı, G. Souliotis, V. Soukeras, S. Tudisco, R.I.M. Vsevolodovna, R. Wheadon, V. Zagatto