Double charge-exchange reactions and the effect of transfer

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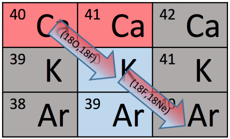
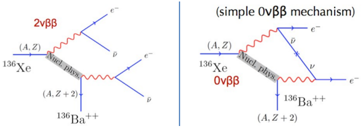
Catania, 17th October 2017

Heavy Ion Double Charge Exchange



$$_{z}a +_{Z} A \rightarrow_{z\pm2} b +_{Z\mp2} B$$

NUMEN @ LNS-INFN



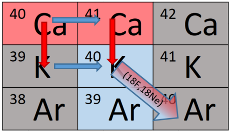
- Input for Nuclear Matrix Elements of $0\nu2\beta$ decay

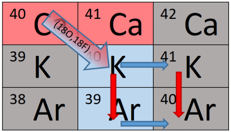
HIDCX @ RCNP / RIKEN

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

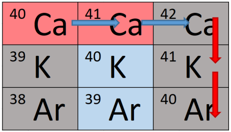
↪*H. Ejiri talk yesterday*

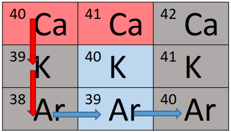
The problem

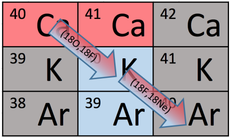


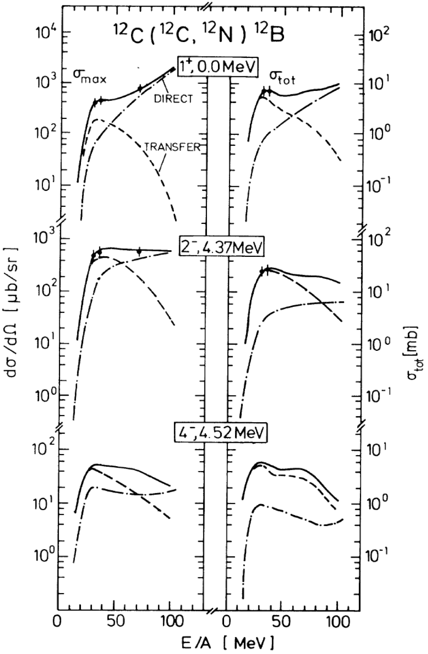


Competing Channels









Single Charge Exchange vs. Transfer

$\Rightarrow$ H. Lenske et al., PRL62 (1989) 1457

- E/A $\rightarrow$ 100 MeV/A
- x States at Q_{opt}

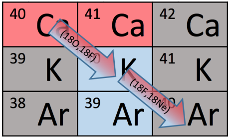
Double CE vs. Transfer

- x Not much known
- ✓ An opportunity to exctract further information on the Wavefunction

Heavy Ions Double Charge Exchange

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

Heavy Ion reactions



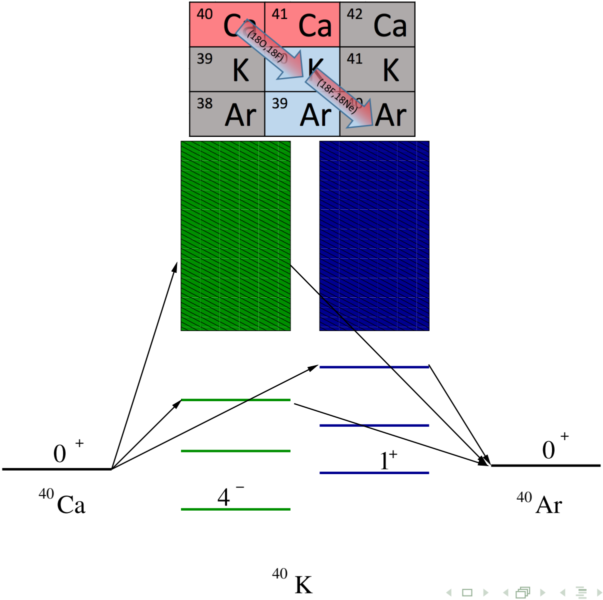
2^{nd} order DWBA

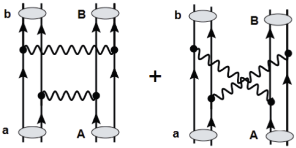
$$\sigma \propto \left| \langle \chi_\beta^- \Psi(Z \mp 2, N \pm 2) \phi(z \pm 2, n \mp 2) | VGV | \Psi(Z, N) \phi(z, n) \chi_\alpha^+ \rangle \right|^2$$

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

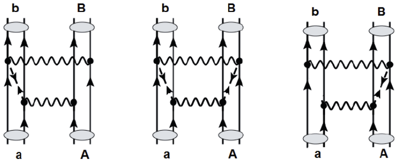
$$G = \sum |\Psi(Z \mp 1, N \pm 1) \phi(z \pm 1, n \mp 1)\rangle G(E) \langle \Psi(Z \mp 1, N \pm 1) \phi(z \pm 1, n \mp 1)|$$

Intermediate states





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



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

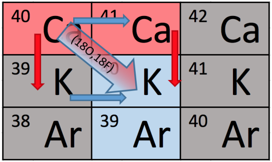
$\hookrightarrow$ H. Lenske's talk yesterday.

Transfer Channels

N^{th} order DWBA transfer

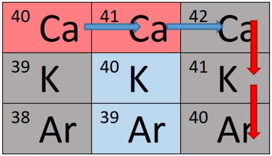
$2nd$ order

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



$4th$ order

- ✗ NO to be fully implemented
- ✓ prior-post-post-post ⇒ no problem if complete basis



↪ *G. Potel talk yesterday*

Ingredients

- Optical potentials ⇒ $t_{\rho\rho}$ 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 → Overlap ≈ SF · s.p. Wavefunction

⇒ Careful with the interference between CE and transfer

For Single Charge Exchange

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

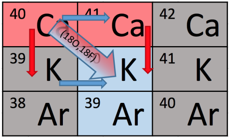
In a not so far future

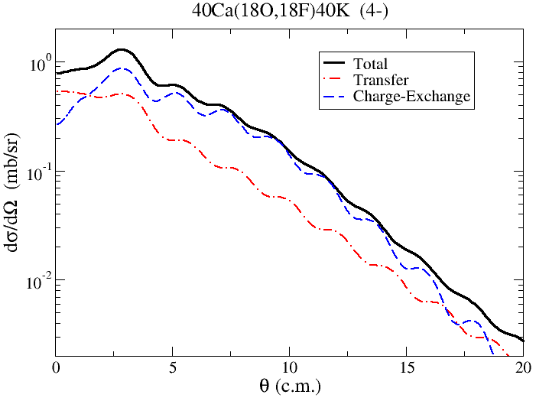
- Calculate transfer from overlaps within the same calculation

Single CE

Preliminary Results

Single Charge Exchange

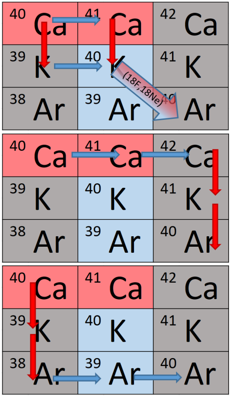


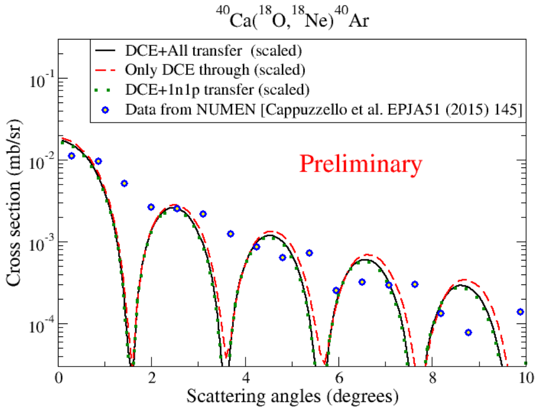


Double CE

Preliminary Results

Double CE



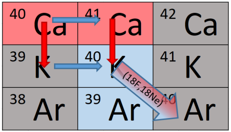


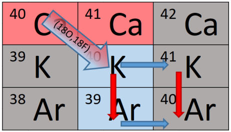
⇒ Only ground states in 2n/2p transfers

⇒ Very small 2n/2p contribution
↪J. Ferreira, J. Lubian, E. Santopinto *et al.*
@ ^{116}Cd(^{20}Ne,^{20}O)^{116}Sn

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

✓ NO here can be under control:





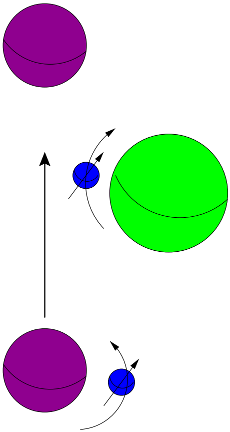
$$\mathcal{T}^{(3)}_{\text{prior,prior,SCE}} \approx (\mathcal{T}^{(2)}_{\text{seq,prior,prior}} + \mathcal{T}^{(2)}_{\text{NO,prior,prior}})\mathcal{T}_{\text{SCE}}$$

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

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

Further suppresion of transfer

Semiclassical Picture



If the transfer process is

- Peripheral
- Gentle

The sign of the projection $\vec{\ell} \cdot \vec{s}$ is likely to be flipped

Basic Idea

Reaction	nucleons	$\vec{\ell}\cdot\vec{s}$	Enhanced Conf.	Supp. Conf.
(t,p)	$(\mathrm{s}_{1/2})^2$	0	$j=\ell\pm s \Rightarrow$????	
$(^{18}\mathrm{O},^{16}\mathrm{O})$	$(\mathrm{d}_{5/2})^2$	$+$	$j=\ell - s \Rightarrow (\mathrm{d}_{3/2})^2$	$j=\ell + s \Rightarrow (\mathrm{d}_{5/2})^2$

$\Rightarrow$ Transfer depends of configurations of target and projectile

$\Rightarrow$ Can be used as a guide to select the projectile for each case

J.A. Lay, L. Fortunato, and A. Vitturi, PRC89 (2014) 034618

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