

# NUMEN

Nodo di Genova

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Componenti:

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Preventivi 2021

# We have got important results!

- The NUMEN collaboration is interested to extract the Double Charge Exchange nuclear matrix elements.
- We have published **the First theoretical article** on Double Charge Exchange:

**Heavy-ion double-charge-exchange and its relation to neutrinoless double- $\beta$  decay, Santopinto, H. García, R.I. Magaña Vsevolodovna, J.Ferretti, Phys. Rev. C98 (2018)(R) 061601**

for the INFN NUMEN experiment.

- In particular, we have demonstrated for the first time the possibility to factorize the Double Charge Exchange (DCE) nuclear matrix elements from the reaction part and the possibility to use them to put constraints on neutrinoless double beta decay matrix elements.

# Heavy-ion double-charge-exchange and its relation to neutrinoless double- $\beta$ decay

Santopinto et al., PHYSICAL REVIEW C 98, 061601 (R) (2018)

- The amplitude between ground states can be computed as follows

$$M_{if}(\mathbf{m}) \xrightarrow{\vec{Q} \rightarrow 0} 2 \left[ \left( \frac{\mathcal{M}_{T \rightarrow T'}^{\text{DGT}} \mathcal{M}_{P \rightarrow P'}^{\text{DGT}}}{\bar{E}_P^{\text{GT}} + \bar{E}_T^{\text{GT}}} \right) + \left( \frac{\mathcal{M}_{T \rightarrow T'}^{\text{DF}} \mathcal{M}_{P \rightarrow P'}^{\text{DF}}}{\bar{E}_P^{\text{F}} + \bar{E}_T^{\text{F}}} \right) \right],$$

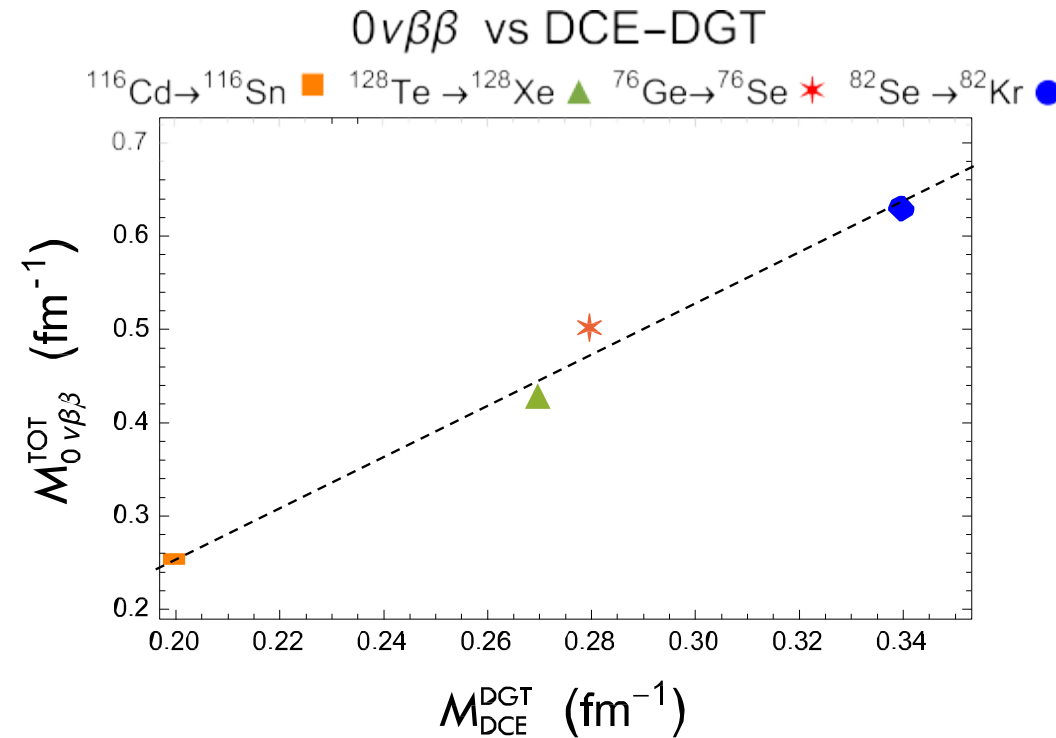
$$\mathcal{M}_{A \rightarrow A'}^{\text{DGT}} = c_{\text{GT}} \langle \Phi_{J'}^{(A')} | \sum_{n,n'} [\vec{\sigma}_n \times \vec{\sigma}_{n'}]^{(0)} \vec{\tau}_n \vec{\tau}_{n'} | \Phi_J^{(A)} \rangle,$$

$$\mathcal{M}_{A \rightarrow A'}^{\text{DF}} = c_{\text{T}} \langle \Phi_{J'}^{(A')} | \sum_{n,n'} \vec{\tau}_n \vec{\tau}_{n'} | \Phi_J^{(A)} \rangle$$

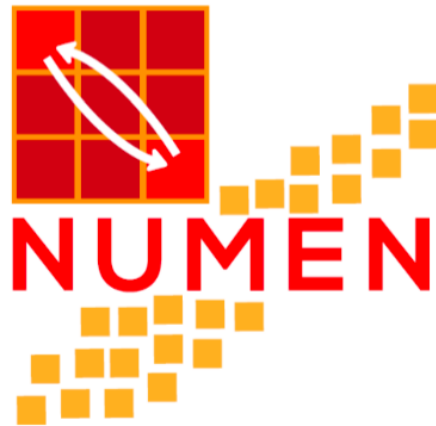
$$\frac{d\sigma}{d\Omega} \xrightarrow{\vec{Q} \rightarrow 0} \frac{k}{k'} \left( \frac{\mu}{4\pi^2 \hbar^2} \right)^2 \left| 2F(\theta) \left( \frac{\mathcal{M}_{T \rightarrow T'}^{\text{DGT}} \mathcal{M}_{P \rightarrow P'}^{\text{DGT}}}{\bar{E}_p^{\text{GT}} + \bar{E}_t^{\text{GT}}} + \frac{\mathcal{M}_{T \rightarrow T'}^{\text{DF}} \mathcal{M}_{P \rightarrow P'}^{\text{DF}}}{\bar{E}_p^{\text{F}} + \bar{E}_t^{\text{F}}} \right) \right|^2$$

$$F(\theta) \xrightarrow{Q_z \rightarrow 0} 2\pi \int_{-\infty}^{\infty} dz \int_0^{\infty} db e^{-izQ_z} b J_0(kb \sin \theta) e^{i\chi(b)}$$

We have shown that there is linear correlation between total nuclear matrix elements of  $0\nu\beta\beta$ -decay and Double Gamow Teller in DCE using IBM:  
Santopinto et al., PHYSICAL REVIEW C 98, 061601 (R) (2018)



# Double Charge Exchange Experiment



- Candidates isotopes:  $^{48}\text{Ca}$ ,  $^{82}\text{Se}$ ,  $^{100}\text{Mo}$ ,  $^{124}\text{Sn}$ ,  $^{128}\text{Te}$ ,  $^{130}\text{Te}$ ,  $^{136}\text{Xe}$ ,  $^{148}\text{Nd}$ ,  $^{150}\text{Nd}$ ,  $^{154}\text{Sm}$ ,  $^{160}\text{Gd}$ ,  $^{198}\text{Pt}$ .

## LIST of ARTICLES NUMEN GE 2019 :

- [1] Analysis of two-nucleon transfer reactions in the  $^{20}\text{Ne} + ^{116}\text{Cd}$  system at 306 MeV, D. Carbone, J. L. Ferreira, S. Calabrese, F. Cappuzzello, M. Cavallaro, A. Hacisalihoglu , H. Lenske, J. Lubian , R. I. Magaña Vsevolodovna, E. Santopinto et al., **may 2020, submitted to PRC**
- [2] Heavy-ion double-charge-exchange and its relation to neutrinoless double- $\beta$  decay, Santopinto, H. García-Tecocoatzi, R.I. Magaña Vsevolodovna, J. Ferretti, **Phys. Rev. C98 (2018)(R ) no.6, 061601.**
- [3] The NUMEN project: NUclear Matrix Elements for Neutrinoless double beta decay, Cappuzzello , et al., **Eur.Phys.J. A54 (2018) no.5, 72.**
- [4] Study of the  $^{18}\text{O} + ^{64}\text{Ni}$  Two-neutron Transfer Reaction at 84 MeV by MAGNEX,Santagati et al., **Acta Phys.Polon. B49 (2018) 381.**
- [5]. Recent results on heavy-ion induced reactions of interest for neutrinoless double beta decay at INFN-LNS NUMEN Collaboration, Manuela Cavallaro et al. **EPJ Web Conf. 223 (2019) 01009.**
- [6] Recent results on Heavy-Ion induced reactions of interest for  $0\nu\beta\beta$  decay, NUMEN Collaboration, C. Agodi et al., **J.Phys.Conf.Ser. 1308 (2019) 1, 012002.**
- [7] Double charge exchange reactions and neutrinoless double beta decay, NUMEN project Collaboration, E. Santopinto et al. **AIP Conf.Proc. 2165 (2019) 1, 020022.**
- [8] The NUMEN project @ LNS: Status and perspectives, F. Cappuzzello, C. Agodi , L. Acosta, C. Altana, P. Amador-Valenzuela et al. **AIP Conf.Proc. 2165 (2019) 1, 020003.**
- [9] New experimental campaign of NUMEN project, NUMEN Collaboration, C. Agodi et al., **AIP Conf.Proc. 2150 (2019) 1, 030001.**

[10] The NUMEN project @ LNS: Status and perspectives, NUMEN Collaboratio, F. Cappuzzello et al., **AIP Conf.Proc. 2150 (2019) 1, 0300.**

[11] Challenges in double charge exchange measurements for neutrino physics, NUMEN Collaboration, D. Torresi et al., **CERN Proc. 1 (2019) 233-238.**

[12] The NUMEN project @ LNS: Status and perspectives, Cappuzzello, F. et al., **NUOVO CIMENTO C-COLLOQUIA AND COMMUNICATIONS IN PHYSICS 42, 57 (2019).**

### **ARTICOLI 2020:**

- 1) Analysis of two-nucleon transfer reactions in the  $^{20}\text{Ne} + ^{116}\text{Cd}$  system at 306 MeV by Diana Carbone, et al., submitted to PRC
- 2) Beta decays with IBFM in even-odd nuclei, Ferretti, Kotila, Magana, Santopinto, in preparation,
- 3) Spectra and one-body transition density for IBFFM for the NUMEN experiment, R. Magana and E. Santopinto, work in progress

## Scientific project 2021:

- Since we have developed during 2019 and 2020 a code for IBFFM (odd odd nuclei) and implemented **Machine Learning methods** to fit the odd odd spectrum (R. Magana), we are now able to describe odd odd nuclei and ( but also even odd or odd even as a sub- product ).
- Moreover we have developed for the first time the formalism for one body transition density for IBFFM (**Excellent work done by Ruslan Magana!**), that has to be completely finished during the 2021 and tested (**2021 project : finish and test**). This is the key ingredient that in the next years it will be plugged inside the Catania-Lenske reaction code that is necessary for the all the details of the NUMEN experiment.
- This is an important result that opens the way to many applications useful for the INFN-NUMEN – exp but also for other INFN experiments present in INFN-GE like neutrino less without closure, double beta decays exp., Torio exp. ( in the case IBFM (even-odd))
- **Responsabilita':**
- E. Santopinto (responsabile nazionale teoria NUMEN)