NINPHA

Hadron and particle physics
Exotic spectroscopy
Nuclear matrix elements
Transport Equations

Responsabile nazionale: Boglione

Nodi:

Cagliari: Murgia
Genova: Santopinto
Pavia: Radici
Perugia:Scopetta
Roma1: Salmè
Torino: Boglione

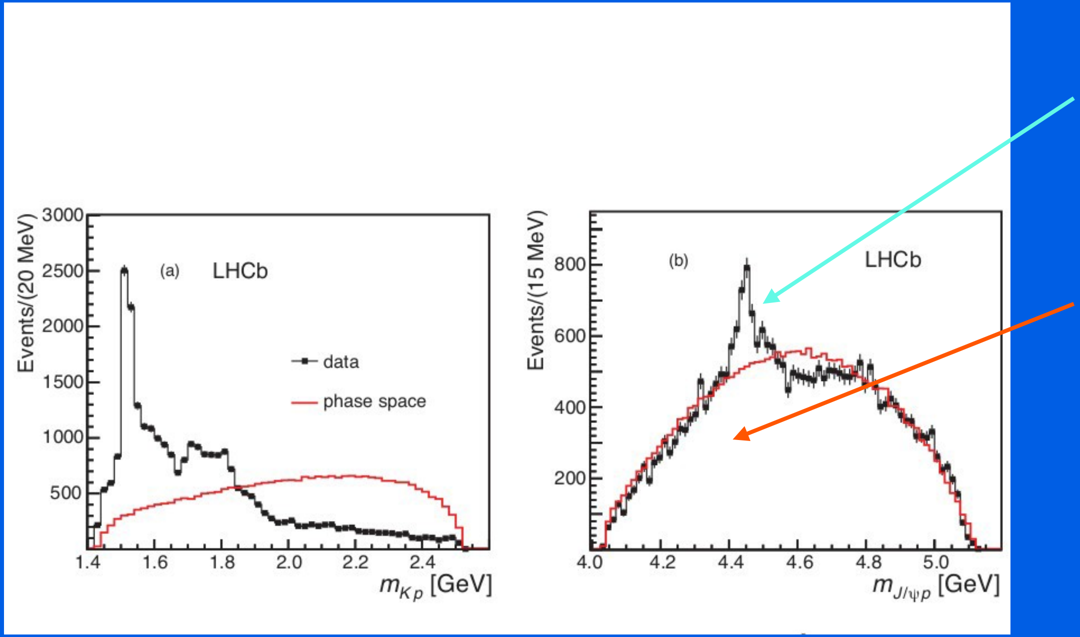
ANAGRAFICA 2019 NINPHA (FTE 4)
Responsabile locale Santopinto

Santopinto (60%), Saracco(40%),Massimo Ottonelli (100%)

Dottorandi :Alessandro Giachino (100%)

Post Doc : Marco Bedolla (100%)

LHCb



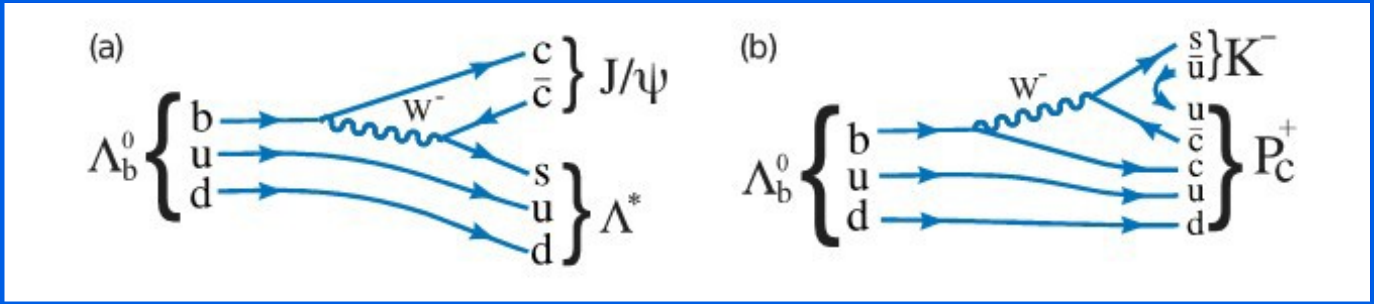
$P_C^+(4450) = (4449.8 \pm 39)$ MeV

$P_C^+(4380) = (4380 \pm 205)$ MeV

**Statistical significance
greater then 9
sigma !**

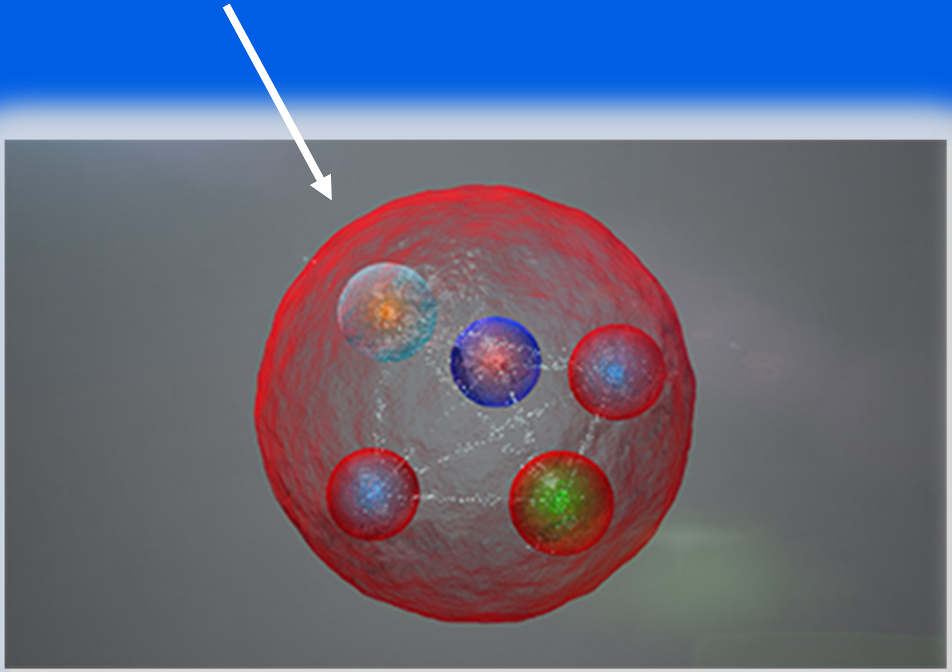
$$\Lambda_b^0 \longrightarrow J/\psi + \Lambda^*, \Lambda^* \longrightarrow K^- + p$$

$$\Lambda_b^0 \longrightarrow P^{0+} + K^-, P^{0+} \longrightarrow J/\Psi + p$$



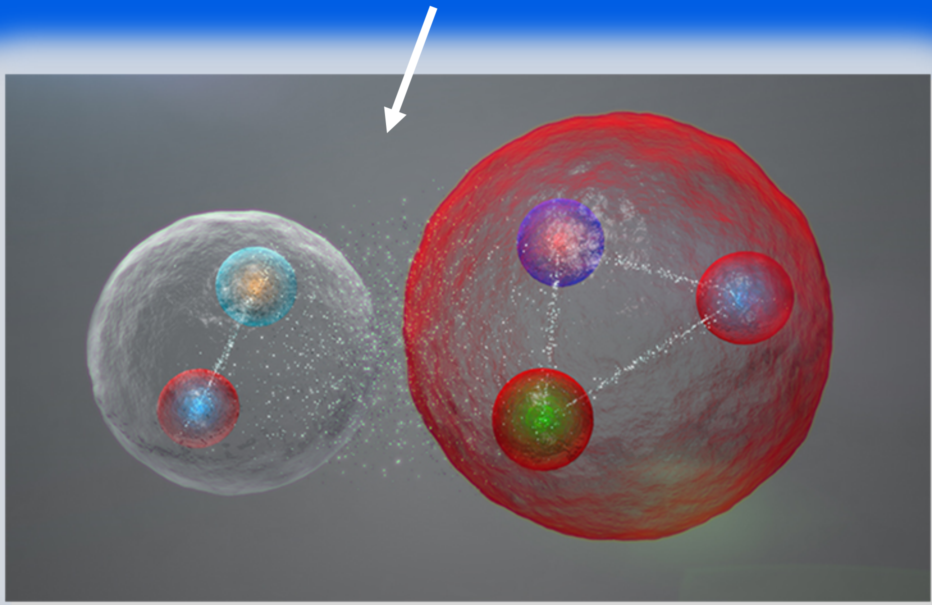
Compact Pentaquark

E. Santopinto , A. Giachino, **Phys.Rev. D96 (2017) no.1, 014014**



Molecular state $D^* \Sigma_C$

Y. Yamaguchi, E. Santopinto, in **Phys.Rev. D96 (2017) no.1, 014018**



Principali pubblicazioni 2017-2018:

c and b :

1) Open-flavor strong decays of open-charm and open-bottom mesons in the 3P0 model, Ferretti and Santopinto, **Phys.Rev. D97 (2018) no.11, 114020**

Exotics:

2)Hidden - charm pentaquark as a meson-baryon molecule with couple channels for D¯(*)Λc and D¯(*) Σ, Y.Yamaguchi, E. Santopinto, in **Phys.Rev. D96 (2017) no.1, 014018**

3)Compact pentaquark structures, E. Santopinto , A. Giachino, **Phys.Rev. D96 (2017) no.1, 014014**

4**)**Hidden-charm and bottom meson-baryon molecules coupled with five quarks,Yamaguchi, Giachino,Osaka,Santopinto, Takeuchi ,Ttakizawa **,Phys.Rev. D96 (2017) no.11, 114031**

5)H. García–Tecocoatzi ,R. Bijker, J. Ferretti , E. Santopinto, **Eur.Phys.J. A53 (2017) no.6, 115**

Transport equations:

6) **I**influence of nuclear reactor materials and core coolant on the characteristics of accelerator driven system **Ann.of Nucl. Energy109(2017),**P. Saracco

7) Propagationand input uncertainties in particle trasport,CJP **55,3 (2017), P.** Saracco

Principali collaborazioni straniere 2019

F. Iachello(Yale U., USA), R. Bijker (UNAM), S. Brodsky (Stanford U., USA), J. Ferretti (Chinese Academy of Sciences, Beijing), Yamaguchi (RIKEN), Hosaka (Osaka U.), Jenni Kotila (Finland), Lubian Rios (Brasil), Szczpaniak (Indiana U.), Takeuchi, Takizawa (RIKEN and Tokio U. Japan)

NUMEN_GR3 preventivi 2019

NUMEN

INFN
What Next

Determining
NME
by Heavy Ion
Double-Charge
Exchange

Resp. GE:
E. Santopinto (30%)
Responsabile Nazionale Teoria: E. Santopinto

Partecipanti:
Post Doc:Ruslan Magagna Voleovoscha (100%)

Objective: measurement of Nuclear Matrix Elements (NME) in Heavy-Ion Double-Charge Exchange (DCE)

Theoretical framework for DCE reactions never developed

- 2016 Genova activity : DCE cross section in eikonal approximation
- 2017 activity: Santopinto, Magagna

The competitive processes(two nucleon transfer and two step single nucleon transfer) to the double charge exchange have been calculated (two article in preparation).
Important results: they do not saturate the double charge exchange cross sections

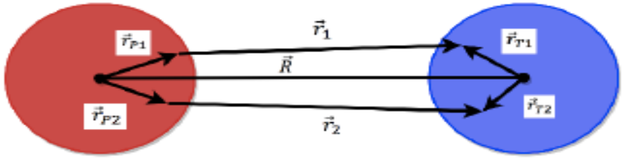
- 2018 activity First Calculations for double charge exchange have been Done!
- 2019 activity :Our results will be appiaid to the forthcoming experimental data.

Primo lavoro teorico sul doppio scambio di carica(DCE)

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

E. Santopinto, H. Garca-Tecocoatzi, R. I. Magana, J. Ferretti (2018)

arXiv:1806.03069 **3 anni di duro lavoro! La teoria del DCE non era mai stata sviluppata prima**



$$\frac{d\sigma}{d\Omega} = \frac{k}{k'}\left(\frac{\mu}{4\pi^2\hbar^2}\right)^2 |T_{\rm if}|^2$$

$$T_{\rm if} = \left\langle \Psi^-_{\vec{k}'}, \Phi_{\rm f} \middle| V \middle| \Psi^+_{\vec{k}} \Phi_{\rm i} \right\rangle = \frac{1}{(2\pi)^{3/2}} \int d\vec{R}\; e^{i\left(\chi(b) - \vec{Q}\cdot\vec{R}\right)} M_{\rm if}(\vec{m})$$

$$M_{\rm if}(\mathbf{m}) = \langle \Phi_{\rm f} | \, V^{\rm DCE} \, | \Phi_{\rm i} \rangle$$

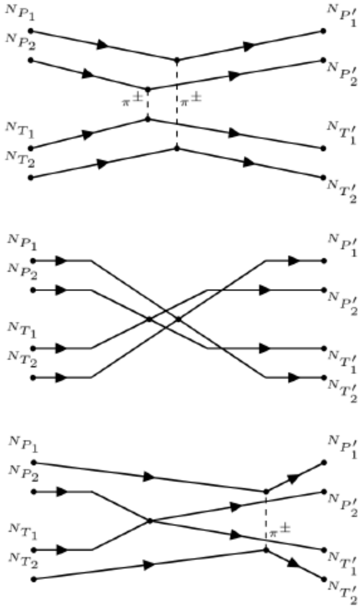


FIG. 1: Leading diagrams in a double-charge-exchange process. From top to bottom, they represent a double-pion-exchange interaction, a double-contact term and a mixed one-pion-exchange plus contact term.

$$V^{\rm DCE} \xrightarrow[\vec{Q}\to 0]{} 2\left[\frac{c_{\rm T}^2}{E_{\rm P}^{\rm F}+E_{\rm T}^{\rm F}} + \frac{c_{\rm GT}^2(\vec{\sigma}_{\rm P1}\cdot\vec{\sigma}_{\rm T1})(\vec{\sigma}_{\rm P2}\cdot\vec{\sigma}_{\rm T2})}{E_{\rm P}^{\rm GT}+E_{\rm T}^{\rm GT}} + \frac{c_{\rm T}c_{\rm GT}(\vec{\sigma}_{\rm P2}\cdot\vec{\sigma}_{\rm T2})}{E_{\rm P}^{\rm GT}+E_{\rm T}^{\rm F}} + \frac{c_{\rm T}c_{\rm GT}(\vec{\sigma}_{\rm P1}\cdot\vec{\sigma}_{\rm T1})}{E_{\rm P}^{\rm F}+E_{\rm T}^{\rm GT}}\right](\vec{\tau}_{\rm P1}\cdot\vec{\tau}_{\rm T1})(\vec{\tau}_{\rm P2}\cdot\vec{\tau}_{\rm T2})$$

$$\frac{d\sigma}{d\Omega} \xrightarrow[\vec{Q}\to 0]{} \frac{k}{k'}\left(\frac{\mu}{4\pi^2\hbar^2}\right)^2 \Bigg| 2F(\theta)\left(\frac{\mathcal{M}^{\rm DGT}_{\rm T\to T'}\mathcal{M}^{\rm DGT}_{\rm P\to P'}}{\bar{E}^{\rm GT}_{\rm P}+\bar{E}^{\rm GT}_{\rm T}} + \frac{\mathcal{M}^{\rm DF}_{\rm T\to T'}\,\mathcal{M}^{\rm DF}_{\rm P\to P'}}{\bar{E}^{\rm F}_{\rm P}+\bar{E}^{\rm F}_{\rm T}}\right)\Bigg|^2 ,$$

where the angular distribution is given by

$$F(\theta) \xrightarrow[Q_z\to 0]{} 2\pi \int_{-\infty}^{\infty} dz \int_0^{\infty} db\, e^{-izQ_z}\, bJ_0(kb\sin\theta)\, e^{i\chi(b)} \, .$$

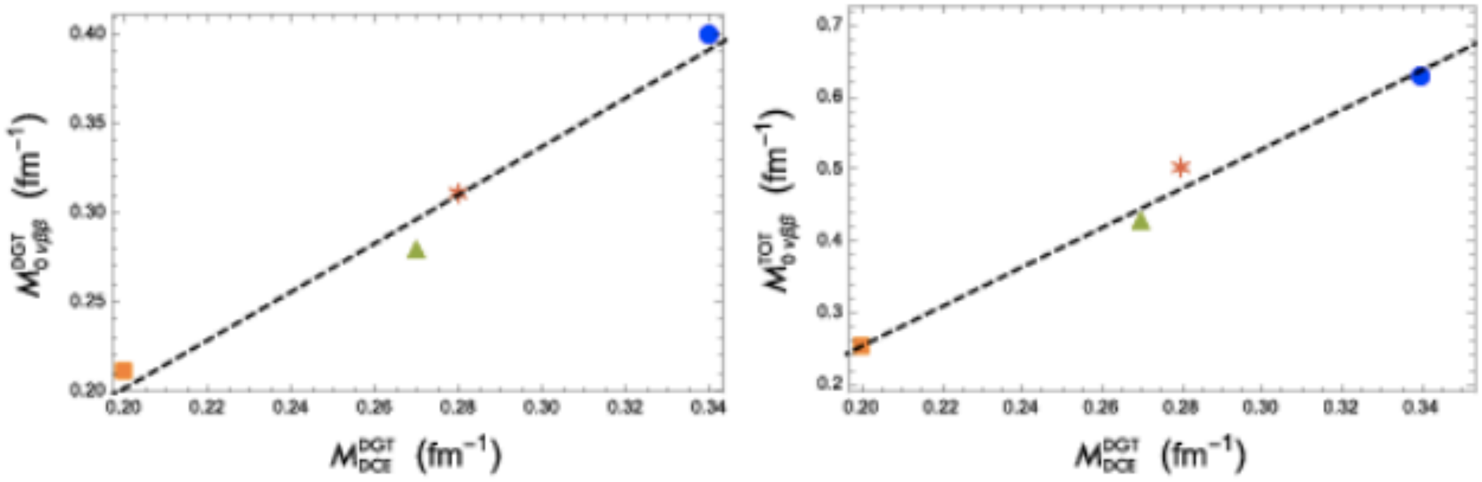
The above expression is written in cylindrical coordinates, where $\vec{Q} = (\vec{Q}_t, Q_z)$ with $|\vec{Q}_t| \simeq k\ \sin\theta$ [39]. It should be noted that in Eq. (13) the nuclear part of the differential cross-section is the sum of DGT and DF

and projectile NMEs. This will open the possibility of extracting neatly DGT and DF NMEs from DCE experimental data at $\theta = 0°$.

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

$$\mathcal{M}^{\mathrm{DGT}}_{\mathrm{A}\to\mathrm{A}'} = c_{\mathrm{GT}}\left\langle \Phi^{(\mathrm{A}')}_{J'} \right| \sum_{n,n'} [\vec{\sigma}_n \times \vec{\sigma}_{n'}]^{(0)} \vec{\tau}_n \vec{\tau}_{n'} \left| \Phi^{(\mathrm{A})}_{J} \right\rangle$$

$$\mathcal{M}^{\mathrm{DF}}_{\mathrm{A}\to\mathrm{A}'} = c_{\mathrm{T}}\left\langle \Phi^{(\mathrm{A}')}_{J'} \right| \sum_{n,n'} \vec{\tau}_n \vec{\tau}_{n'} \left| \Phi^{(\mathrm{A})}_{J} \right\rangle$$



(a) (b)

FIG. 3: Correlation between our calculated DCE-DGT NMEs and (a) $0\nu\beta\beta$-DGT NMEs [62] and (b) $0\nu\beta\beta$-total NMEs [62]. The orange squares, green triangles, red stars and blue circles stand for ^{116}Cd → ^{116}Sn, ^{128}Te → ^{128}Xe, ^{82}Se→ ^{82}Kr and ^{76}Ge → ^{76}Se data, respectively.

In $0^+ \rightarrow 0^+$ DCE reactions at $\theta = 0°$, a contribution is made by both DGT and DF NMEs, though the DCE-DGT contribution is the dominant one. For this reason, one can place an upper limit on DCE-DGT NMEs, which will correspond to an upper limit on $0\nu\beta\beta$ NMEs, thanks to the existence of the linear correlation between them.