Λ_b and Ξ_b weak decays into Λ_c^* or Ξ_c^* and dynamics of Λ_c^*, Ξ_c^*

E. Oset, IFIC and University of Valencia, W.H. Liang, M. Bayar, J.J.Xie, R.Pavao, J.Nieves

Generation of the $\Lambda_c(2595)$ (1/2-) and $\Lambda_c(2625)$ (3/2-) states

The Λ_b -> π- $\Lambda_c(2595)$, Λ_b -> π- $\Lambda_c(2595)$ reactions

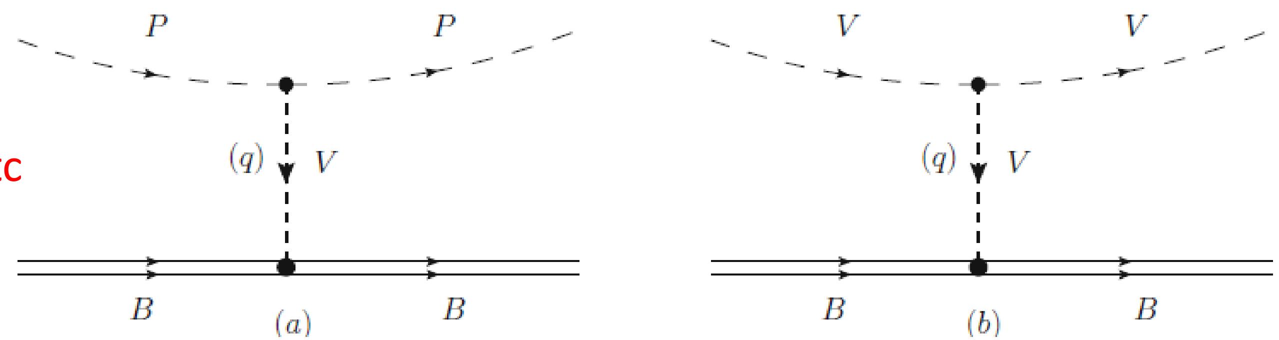
The semileptonic Λ_b -> ν l $\Lambda_c(2595)$, ν l $\Lambda_c(2595)$ reactions

Extension to Ξ_b decays into the Ξ_c (1/2-) and Ξ_c (3/2-) resonances

Generation of the $\Lambda_c(2595)$ (1/2-) and $\Lambda_c(2625)$ (3/2-)

We use the local Hidden Gauge Approach (Bando et al.) :
Chiral Lagrangians come from exchange of vector mesons, the theory extends the Chiral Lagrangians incorporating the interaction of vector mesons

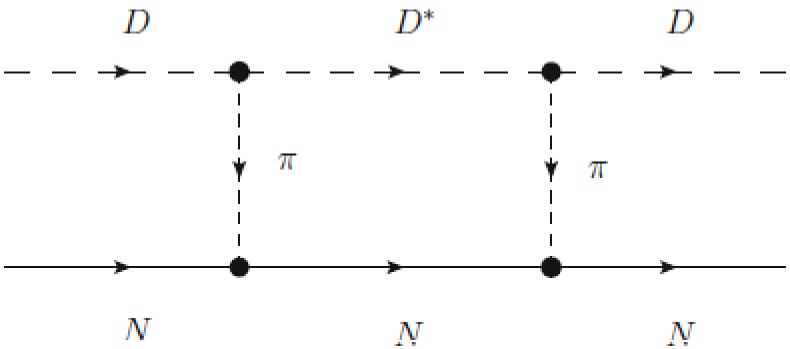
D N , D* N, etc

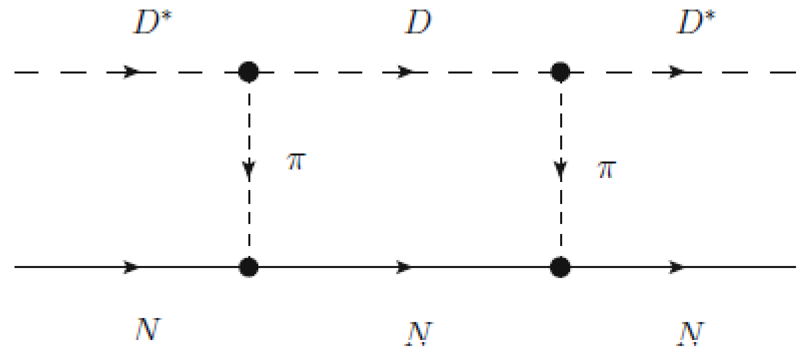


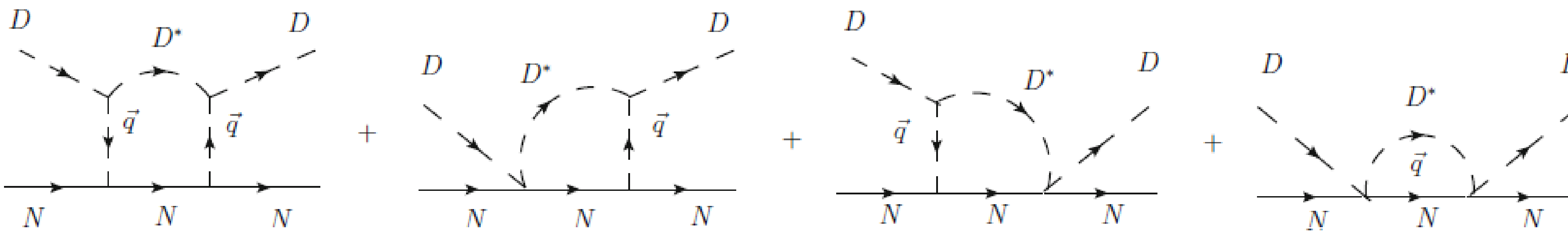
$$V_{ij} = -C_{ij}\frac{1}{4f^2}(2\sqrt{s}-M_{B_i}-M_{B_j})\sqrt{\frac{M_{B_i}+E_i}{2M_{B_i}}}\sqrt{\frac{M_{B_j}+E_j}{2M_{B_j}}}, \quad (1)$$

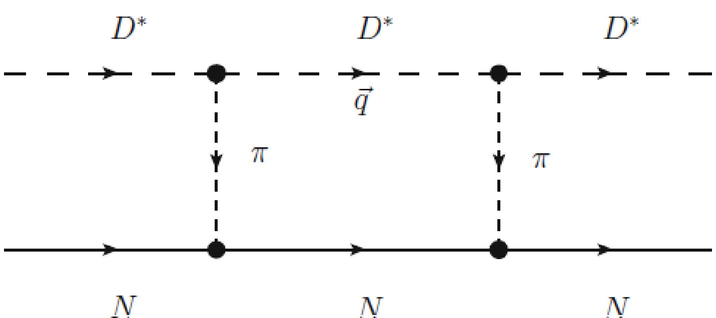
When heavy quarks are involved one can see that the exchange of light vectors respects Heavy Quark Spin Symmetry because the heavy quarks act as spectators in this exchange

Mixture of PB and VB states









$$\mathcal{L}_{VPP} = -ig\,\langle [P, \partial_\mu P] V^\mu \rangle$$

$$\mathcal{L}_{VVP} = \frac{G'}{\sqrt{2}} \epsilon^{\mu\nu\alpha\beta} \langle \partial_\mu V_\nu \partial_\alpha V_\beta P \rangle$$

$g = m_V/2f_\pi$ with $m_V \approx 780\,\mathrm{MeV}$, $f_\pi = 93\,\mathrm{MeV}$

$$P = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -\frac{2\eta_8}{\sqrt{6}} \end{pmatrix},$$

$$V_\mu = \begin{pmatrix} \frac{\rho^0}{\sqrt{2}} + \frac{\omega}{\sqrt{2}} & \rho^+ & K^{*+} \\ \rho^- & -\frac{\rho^0}{\sqrt{2}} + \frac{\omega}{\sqrt{2}} & K^{*0} \\ K^{*-} & \bar{K}^{*0} & \phi \end{pmatrix}_\mu .$$

Baryon states with open charm in the extended local hidden gauge approach
W.H. Liang (Guangxi Normal U.), T. Uchino, C.W. Xiao, E. Oset (Valencia U. & Valencia U., IFIC). Feb 21, 2014. 23 pp.
Published in **Eur.Phys.J. A51 (2015) no.2, 16**

A unitary scheme in coupled channels is used $T=(1-VG)^{-1}V$

Table 4. The coupling constants to various channels for the poles in the $I=0$, $J^P=1/2^-$ sector, with the anomalous term and taking $q_{\rm max}^{B,V,P}=800, 737, 500\,{\rm MeV}$. In bold face we highlight the main components.

$2592.26+i0.56$	DN	$\pi\Sigma_c$	$\eta\Lambda_c$	
g_i	$\mathbf{-8.18+i0.61}$	$\mathbf{0.54+i0.00}$	$-0.40-i0.03$	
$g_i\,G_i^{II}$	$\mathbf{13.88-i1.06}$	$\mathbf{-10.30-i0.69}$	$1.76-i0.14$	
	D^*N	$\rho\Sigma_c$	$\omega\Lambda_c$	$\phi\Lambda_c$
g_i	$\mathbf{9.81+i0.77}$	$-0.45-i0.04$	$0.42+i0.03$	$-0.59-i0.05$
$g_i\,G_i^{II}$	$\mathbf{-26.51-i2.10}$	$2.07+i0.17$	$-2.31-i0.19$	$2.10+i0.17$

Table 2. The coupling constants to various channels for the poles in the $I=0$, $J^P=3/2^-$ sector of D^*N and coupled channels, with the anomalous term and taking $q_{\rm max}^{B,V}=800, 737\,{\rm MeV}$. In bold face we highlight the main components.

2628.35	D^*N	$\rho\Sigma_c$	$\omega\Lambda_c$	$\phi\Lambda_c$
g_i	$\mathbf{10.11}$	-0.55	0.49	-0.68
$g_i\,G_i^{II}$	$\mathbf{-29.10}$	2.60	-2.78	2.50

Weak decays of hadrons: ab initio calculations from QCD or using quark models suffer from large uncertainties : usually two orders of magnitude!!

J. Sun, N. Wang, Q. Chang and Y. Yang, Adv. High Energy Phys. **2015**, 104378 (2015) [arXiv:1504.01286 [hep-ph]].

In most cases there are added uncertainties because of lack of knowledge on final state interaction of hadrons or the nature of hadronic states formed in the final state. Final state interaction considered in

Dedonder, Kaminski, Lesniak,Loiseau, D^0 \to K_S^0 \pi^+ \pi^- decays, PRD 2104

A different approach has been developed by looking explicitly into the final state interaction of hadrons and calculating ratios of rates to eliminate the microscopical process of the weak interaction and earlier formation of hadronic components.

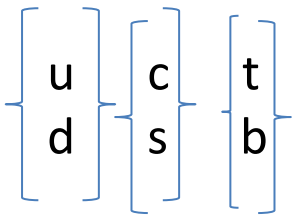
Weak decays of heavy hadrons into dynamically generated resonances

Int.J.Mod.Phys. E25 (2016) 1630001

Eulogio Oset* Wei-Hong Liang Melahat Bayar Ju-Jun Xie Lian Rong Dai Miguel Albaladejo
Marina Nielsen Takayasu Sekihara Fernando Navarra Luis Roca Maxim Mai Juan Nieves
Jorgivan Morais Dias Alberto Feijoo Volodymyr K. Magas Angels Ramos Kenta Miyahara
Tetsuo Hyodo Daisuke Jido Michael Döring Raquel Molina Hua-Xing Chen En Wang
Lisheng Geng Natsumi Ikeno Pedro Fernández-Soler Zhi Feng Sun

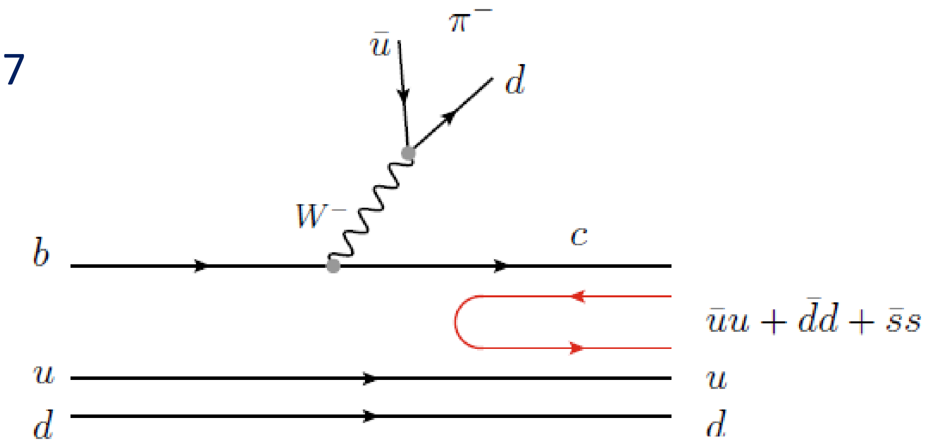
$\Lambda_b \to \pi^-(D_s^-)\Lambda_c(2595),\ \pi^-(D_s^-)\Lambda_c(2625)$ decays and $DN,\ D^*N$ molecular components

W. H. Liang, M. Bayar, E. Oset, EPJC 2017



Λ_b

S=0, I=0



$$|\Lambda_b\rangle = \frac{1}{\sqrt{2}}|b(ud - du)\rangle \qquad |H\rangle = \frac{1}{\sqrt{2}}|c(ud - du)\rangle$$

The hadronization converts this state into $|H'\rangle$.

$$|H'\rangle = \frac{1}{\sqrt{2}}|c(\bar{u}u + \bar{d}d + \bar{s}s)(ud - du)\rangle.$$

$$|H'\rangle = \frac{1}{\sqrt{2}}\sum_{i=1}^{3}|P_{4i}\, q_i(ud - du)\rangle$$

$$P \equiv (q\bar{q}) = \begin{pmatrix} u\bar{u} & u\bar{d} & u\bar{s} & u\bar{c} \\ d\bar{u} & d\bar{d} & d\bar{s} & d\bar{c} \\ s\bar{u} & s\bar{d} & s\bar{s} & s\bar{c} \\ c\bar{u} & c\bar{d} & c\bar{s} & c\bar{c} \end{pmatrix}$$

$$P \to \phi \equiv \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{3}}\eta + \frac{1}{\sqrt{6}}\eta' & \pi^+ & K^+ & \bar{D}^0 \\ \pi^- & -\frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{3}}\eta + \frac{1}{\sqrt{6}}\eta' & K^0 & D^- \\ K^- & \bar{K}^0 & -\frac{1}{\sqrt{3}}\eta + \sqrt{\frac{2}{3}}\eta' & D_s^- \\ D^0 & D^+ & D_s^+ & \eta_c \end{pmatrix}$$

$$|H'\rangle = \frac{1}{\sqrt{2}}[D^0 u(ud-du) + D^+ d(ud-du) + D_s^+ s(ud-du)].$$

F. E. Close convention

$$|p\rangle = \frac{1}{\sqrt{2}}|u(ud-du)\rangle,$$

$$|n\rangle = \frac{1}{\sqrt{2}}|d(ud-du)\rangle,$$

$$|\Lambda\rangle = \frac{1}{\sqrt{12}}|(usd-dsu)+(dus-uds)+2(sud-sdu)\rangle$$

$$|H'\rangle = \left|D^0 p + D^+ n + \sqrt{\frac{2}{3}} D_s^+ \Lambda\right\rangle$$
$$\simeq \sqrt{2}|DN, I=0\rangle,$$

One should change the sign to the Λ for consistency with chiral Lagrangians

Same decomposition for D* N from flavor considerations

c quark
$$|JM\rangle = \sum_m \mathcal{C}\left(1\frac{1}{2}J;\ m, M-m\right) Y_{1m}\left|\frac{1}{2}, M-m\right\rangle$$

c quark in L=1 , such that c u d has negative parity

q qbar from hadronization
$$|00\rangle = \sum_{M_3,S_3} \mathcal{C}(110;\ M_3, S_3, 0) Y_{1M_3}|1\ S_3\rangle$$

$^3P_0$ configuration

$$|JM\rangle|00\rangle = \frac{1}{4\pi}\sum_j (-1)^{j-J+1/2}\sqrt{2j+1}\,W\left(1\frac{1}{2}Jj;\frac{1}{2}\frac{1}{2}\right)$$
$$\times|JM, \text{meson-baryon}\rangle \quad \equiv \sum_j \mathcal{C}(j, J)|JM, \text{meson-baryon}\rangle$$

j is the spin of the meson, 0 for P, 1 for V

Table 1 $\mathcal{C}(j, J)$ coefficients in Eq. (24)

$\mathcal{C}(j, J)$	$J = 1/2$	$J = 3/2$
(pseudoscalar) $j = 0$	$\frac{1}{4\pi}\frac{1}{2}$	0
(vector) $j = 1$	$\frac{1}{4\pi}\frac{1}{2\sqrt{3}}$	$-\frac{1}{4\pi}\frac{1}{\sqrt{3}}$

$$\mathcal{L}_{W,\pi} \sim W^{\mu}\partial_{\mu}\phi \qquad \mathcal{L}_{\bar{q}Wq} = \bar{q}_{\rm fin} W_{\mu}\gamma^{\mu}(1-\gamma_5)q_{\rm in}$$

$$V_P \sim q^0 + \vec{\sigma}\cdot\vec{q}$$

$$J = 1/2 : q^0\Big|_{\text{quark level}} \to i\frac{w_\pi}{q}\text{ME}(q)\vec{\sigma}\cdot\vec{q}\Big|_{\text{macroscopical level}}$$

$$J = 3/2 : q^0\Big|_{\text{quark level}} \to -i\frac{w_\pi}{q}\text{ME}(q)\sqrt{3}\vec{S}^{+}\cdot\vec{q}\Big|_{\text{macroscopical level}}$$

Matrix element between Λ_b and Λ_c^*

$$\left\langle JM' \left| \vec{\sigma}\cdot\vec{q} \right| \frac{1}{2}M \right\rangle \to \quad iq\delta_{J,\frac{1}{2}}$$ ME(q) macroscopical level

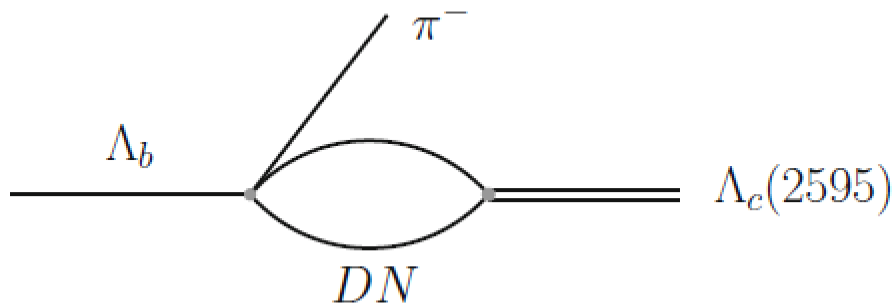
$$\text{ME}(q) \equiv \int r^2 \text{d}r\ j_1(qr)\ \varphi_{\rm in}(r)\ \varphi^{*}_{\rm fin}(r)$$

Difficult and uncertain to evaluate, but it cancels in ratios.

Final operator

$$\left(iq + i\frac{w_\pi}{q}\vec{\sigma}\cdot\vec{q}\right)\delta_{J,\frac{1}{2}} + \left(-i\frac{w_\pi}{q}\sqrt{3}\vec{S}^{+}\cdot\vec{q}\right)\delta_{J,\frac{3}{2}}$$

Up to the unknown factor ME and global factors



$$t_R = V_P\,\sqrt{2}\,G_{DN}\cdot g_{R,DN}$$

$$t_R = \left(iq + i\frac{w_\pi}{q}\vec{\sigma}\cdot\vec{q}\right)\left(\frac{1}{2}G_{DN}\,g_{R,DN} + \frac{1}{2\sqrt{3}}G_{D^*N}\,g_{R,D^*N}\right)\delta_{J,\frac{1}{2}}$$
$$-\left(+i\frac{w_\pi}{q}\sqrt{3}\vec{S}^+\cdot\vec{q}\right)\frac{1}{\sqrt{3}}G_{D^*N}\,g_{R,D^*N}\,\delta_{J,\frac{3}{2}}$$

$$\Gamma_R = \frac{1}{2\pi}\frac{M_{\Lambda_c^*}}{M_{\Lambda_b}}\overline{\sum}\sum|t_R|^2\,p_{\pi^-}$$

Prediction

$$\frac{\Gamma[\Lambda_b \to \pi^- \Lambda_c(2595)]}{\Gamma[\Lambda_b \to \pi^- \Lambda_c(2625)]} = 0.76$$

Experiment

$$\left.\frac{\Gamma[\Lambda_b \to \pi^- \Lambda_c(2595)]}{\Gamma[\Lambda_b \to \pi^- \Lambda_c(2625)]}\right|_{\text{Exp.}} = 1.03 \pm 0.60$$

Prediction

$$\frac{\Gamma[\Lambda_b \to D_s^- \Lambda_c(2595)]}{\Gamma[\Lambda_b \to D_s^- \Lambda_c(2625)]} = 0.54$$

Prediction

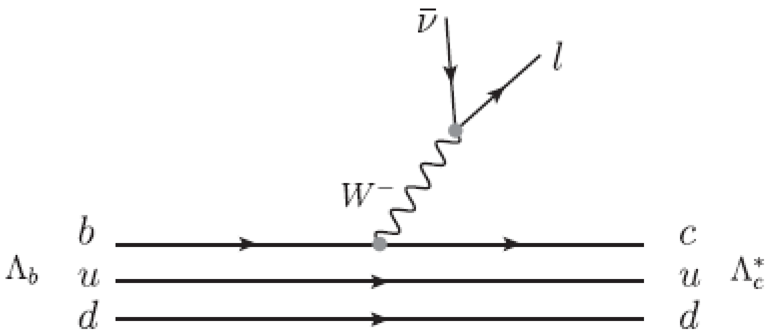
$$\mathrm{BR}[\Lambda_b \to D_s^- \Lambda_c(2595)] \sim (2.22 \pm 0.97) \times 10^{-4}$$
$$\mathrm{BR}[\Lambda_b \to D_s^- \Lambda_c(2625)] \sim (3.03 \pm 1.70) \times 10^{-4}$$

If the D*N coupling had opposite sign there is a near cancellation and sheer disagreement with experiment.

Relativistic corrections are about 30% for individual rates, but about 1% en the ratios. Uncertainties from neglecting the Λ D_s channel about 20%.

Semileptonic $\Lambda_b \to \bar{\nu}_l l \Lambda_c(2595)$ and $\Lambda_b \to \bar{\nu}_l l \Lambda_c(2625)$ decays in the molecular picture of $\Lambda_c(2595)$ and $\Lambda_c(2625)$

W. H. Liang, E. Oset and Z.S. Xie, PRD 2017



$$T = -iG_F \frac{V_{bc}}{\sqrt{2}} L^\alpha Q_\alpha V_{\rm had}$$

$$L^\alpha \equiv \bar{u}_l \gamma^\alpha (1-\gamma_5) v_\nu, \quad Q_\alpha \equiv \bar{u}_c \gamma_\alpha (1-\gamma_5) u_b$$

$$\sum_{\rm pol} L^\alpha L^{\dagger\beta} = {\rm tr}\left[\gamma^\alpha (1-\gamma_5) \frac{p\!\!/_\nu - m_\nu}{2m_\nu} (1+\gamma_5) \gamma^\beta \frac{p\!\!/_l + m_l}{2m_l}\right]$$

$$= 2\frac{p_\nu^\alpha p_l^\beta + p_l^\alpha p_\nu^\beta - p_\nu \cdot p_l g^{\alpha\beta} - i\epsilon^{\rho\alpha\sigma\beta} p_{\nu\rho} p_{l\sigma}}{m_\nu m_l}.$$

$$Q_\alpha \longrightarrow V_P \sim q^0 + \vec{\sigma}\cdot\vec{q}$$

$$\sum_{\rm lepton\ pol} L^\alpha L^{\dagger\beta} Q_\alpha Q_\beta^\dagger = \frac{2}{m_\nu m_l}[2p_\nu^0 p_l^0 - p_\nu \cdot p_l + 4p_\nu^0 \vec{p}_l \cdot \vec{\sigma}$$

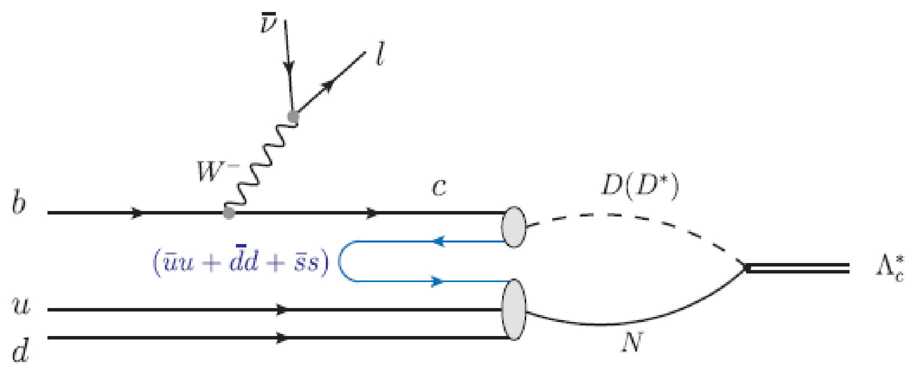
$$+ (\vec{p}_\nu \cdot \vec{\sigma})(\vec{p}_l \cdot \vec{\sigma}) + (\vec{p}_l \cdot \vec{\sigma})(\vec{p}_\nu \cdot \vec{\sigma}) + (p_\nu \cdot p_l)(\vec{\sigma}\cdot\vec{\sigma})]$$

$$\sum_{\text{lepton pol}} L^{\alpha} L^{\dagger\beta} Q_{\alpha} Q^{\dagger}_{\beta} \quad = \frac{2}{m_\nu m_l}[2p^0_\nu p^0_l - p_\nu \cdot p_l + 2\vec{p}_\nu \cdot \vec{p}_l + 3p_\nu \cdot p_l] \quad = \frac{8}{m_\nu m_l} p^0_\nu p^0_l$$

$$\overline{\sum}\sum L^{\alpha} L^{\dagger\beta} Q_{\alpha} Q^{\dagger}_{\beta} \equiv \frac{8}{m_\nu m_l} p^0_\nu p^0_l \frac{1}{2\vec{q}^2} \sum_{M,M'} \begin{cases} \langle \frac{1}{2}M|\vec{\sigma}\cdot\vec{q}|\frac{1}{2}M'\rangle\langle\frac{1}{2}M'|\vec{\sigma}\cdot\vec{q}|\frac{1}{2}M\rangle, & \text{for } J=1/2 \\ 3\langle\frac{1}{2}M|\vec{S}\cdot\vec{q}|\frac{3}{2}M'\rangle\langle\frac{3}{2}M'|\vec{S}^{+}\cdot\vec{q}|\frac{1}{2}M\rangle, & \text{for } J=3/2 \end{cases}$$

$$\overline{\sum}\sum L^{\alpha} L^{\dagger\beta} Q_{\alpha} Q^{\dagger}_{\beta} \equiv A_J \frac{8}{m_\nu m_l} p^0_\nu p^0_l$$

with $A_{1/2} = 1$ and $A_{3/2} = 2$.



$$\overline{\sum}\sum |T|^2 = C\frac{8}{m_\nu m_l} p^0_\nu p^0_l A_J V_{\text{had}}(J)$$

$$A_J V_{\text{had}}(J) \equiv \begin{cases} |\frac{1}{2}G_{DN}\cdot g_{R,DN} + \frac{1}{2\sqrt{3}}G_{D^*N}\cdot g_{R,D^*N}|^2, & \text{for } J=1/2 \\ 2|\frac{1}{\sqrt{3}}G_{D^*N}\cdot g_{R,D^*N}|^2, & \text{for } J=3/2 \end{cases}$$

$$\frac{d\Gamma}{dM_{\rm inv}} = 2M_{\Lambda_b} 2M_{\Lambda_c^*} 2m_\nu 2m_l \frac{1}{4M_{\Lambda_b}^2} \frac{1}{(2\pi)^3} p_{\Lambda_c^*} \tilde{p}_l \overline{\sum} \sum |T|^2$$

Prediction

$$\frac{\Gamma[\Lambda_b \to \bar{\nu}_l l \Lambda_c(2595)]}{\Gamma[\Lambda_b \to \bar{\nu}_l l \Lambda_c(2625)]} = 0.391$$

Experiment

$$\left.\frac{\Gamma[\Lambda_b \to \bar{\nu}_l l \Lambda_c(2595)]}{\Gamma[\Lambda_b \to \bar{\nu}_l l \Lambda_c(2625)]}\right|_{\rm Exp.} = 0.6^{+0.4}_{-0.3}$$

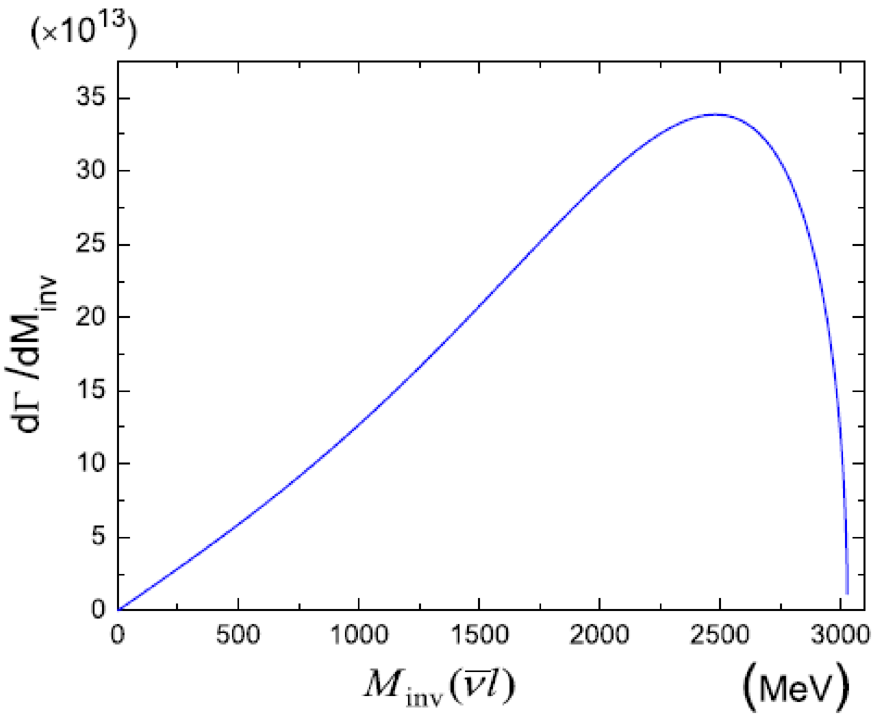
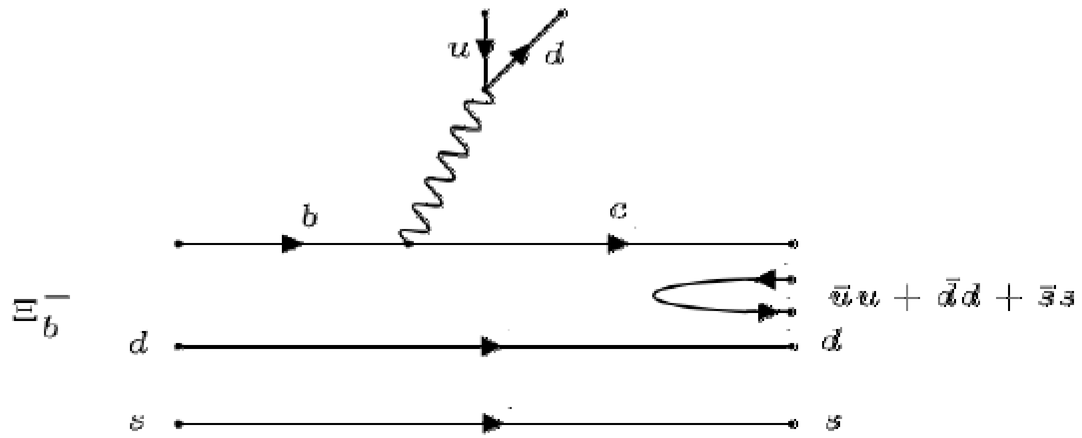


FIG. 3. $\frac{d\Gamma}{dM_{\rm inv}}$ for the $(\bar{\nu}l)$ pair as a function of $M_{\rm inv}(\bar{\nu}l)$ in the $\Lambda_b \to \bar{\nu}_l l \Lambda_c(2595)$ decay.

Relativistic corrections of the order of 30 %, but of 1% in the ratios.

Predictions for $\Xi_b^- \to \pi^- \left(D_s^-\right)\ \Xi_c^0(2790)\ \left(\Xi_c^0(2815)\right)$ and $\Xi_b^- \to \bar{\nu}_l l\ \Xi_c^0(2790)\ \left(\Xi_c^0(2815)\right)$

R. P. Pavao, W. H. Liang, J. Nieves and E. O, EPJC 2017.



$$\left|\Xi_b^-\right\rangle \equiv \frac{1}{\sqrt{2}}\left|b\,(ds - sd)\right\rangle \qquad \left|H\right\rangle = \frac{1}{\sqrt{2}}\left|c\,(ds - sd)\right\rangle$$

$$\left|H'\right\rangle = \frac{1}{\sqrt{2}}\sum_{i=1}^{3}\left|P_{4i}\ q_i\,(ds - sd)\right\rangle$$

$$\phi \equiv \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{3}}\eta + \frac{1}{\sqrt{6}}\eta' & \pi^+ & K^+ & \bar{D}^0 \\ \pi^- & -\frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{3}}\eta + \frac{1}{\sqrt{6}}\eta' & K^0 & D^- \\ K^- & \bar{K}^0 & -\frac{1}{\sqrt{3}}\eta + \sqrt{\frac{2}{3}}\eta' & D_s^- \\ D^0 & D^+ & D_s^+ & \eta_c \end{pmatrix}$$

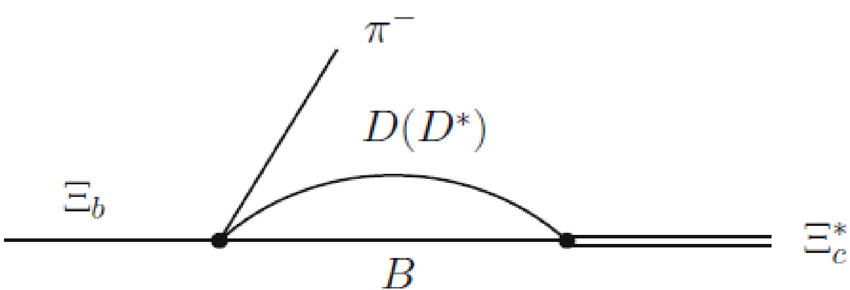
$$|H'\rangle = \frac{1}{\sqrt{2}}\left[\left|D^0 u\,(ds - sd)\right\rangle + \left|D^+ d\,(ds - sd)\right\rangle + \left|D_s^+ s\,(ds - sd)\right\rangle\right]$$

From Miyahara, Hyodo, Oka , Nieves, E. O , PRC 2017

Baryon	3q representation
p	$\frac{1}{\sqrt{2}}u(ud - du)$
n	$\frac{1}{\sqrt{2}}d(ud - du)$
Σ^+	$\frac{1}{\sqrt{2}}u(su - us)$
Σ^0	$\frac{1}{2}\left[u(ds - sd) - d(su - us)\right]$
Σ^-	$\frac{1}{\sqrt{2}}d(ds - sd)$
Ξ^0	$\frac{1}{\sqrt{2}}s(su - us)$
Ξ^-	$\frac{1}{\sqrt{2}}s(ds - sd)$
Λ	$\frac{1}{2\sqrt{3}}\left[u(ds - sd) + d(su - us) - 2s(ud - du)\right]$

$$|H'\rangle = \frac{1}{\sqrt{2}}\left|D^0\Sigma^0\right\rangle + \left|D^+\Sigma^-\right\rangle - \frac{1}{\sqrt{6}}\left|D^0\Lambda\right\rangle$$

$$|H'\rangle = -\sqrt{\frac{3}{2}}\left|\Sigma D(J = \tfrac{1}{2})\right\rangle + \frac{1}{\sqrt{6}}\left|\Lambda D(J = \tfrac{1}{2})\right\rangle$$

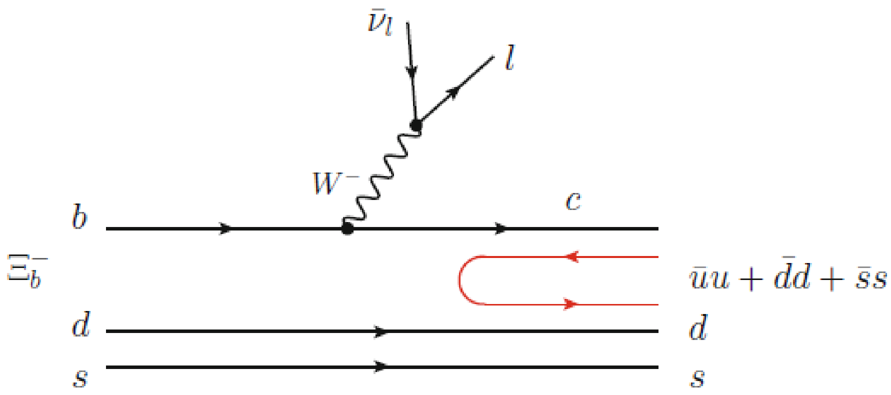


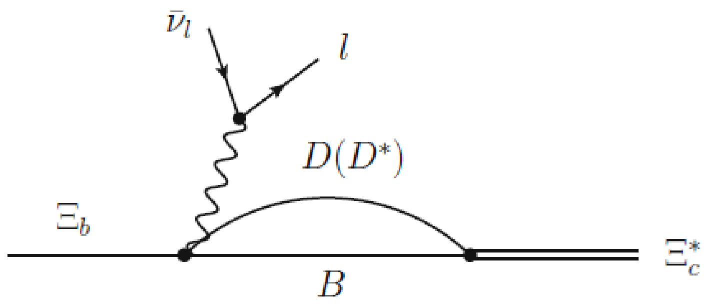
$$\Gamma_{\Xi_b \to \pi^- \Xi_c^*} = \frac{1}{2\pi} \frac{M_{\Xi_c^*}}{M_{\Xi_b}} q \overline{\sum} \sum |t|^2$$

$$J = \frac{3}{2} : \overline{\sum} \sum |t|^2 = C^2 \, 2\omega_\pi^2 \times \left| \frac{1}{\sqrt{3}} \left(-\sqrt{\frac{3}{2}} \right) g_{R,\Sigma D^*} \, G_{\Sigma D^*} + \frac{1}{\sqrt{3}} \frac{1}{\sqrt{6}} g_{R,\Lambda D^*} \, G_{\Lambda D^*} \right|^2$$

$$J = \frac{1}{2} : \overline{\sum} \sum |t|^2 = C^2 \left(q^2 + \omega_\pi^2 \right) \times \left| \frac{1}{2} \left(-\sqrt{\frac{3}{2}} \right) g_{R,\Sigma D} \, G_{\Sigma D} + \frac{1}{2} \frac{1}{\sqrt{6}} g_{R,\Lambda D} \, G_{\Lambda D} + \frac{1}{2\sqrt{3}} \left(-\sqrt{\frac{3}{2}} \right) g_{R,\Sigma D^*} \, G_{\Sigma D^*} + \frac{1}{2\sqrt{3}} \frac{1}{\sqrt{6}} g_{R,\Lambda D^*} \, G_{\Lambda D^*} \right|^2$$

Semileptonic



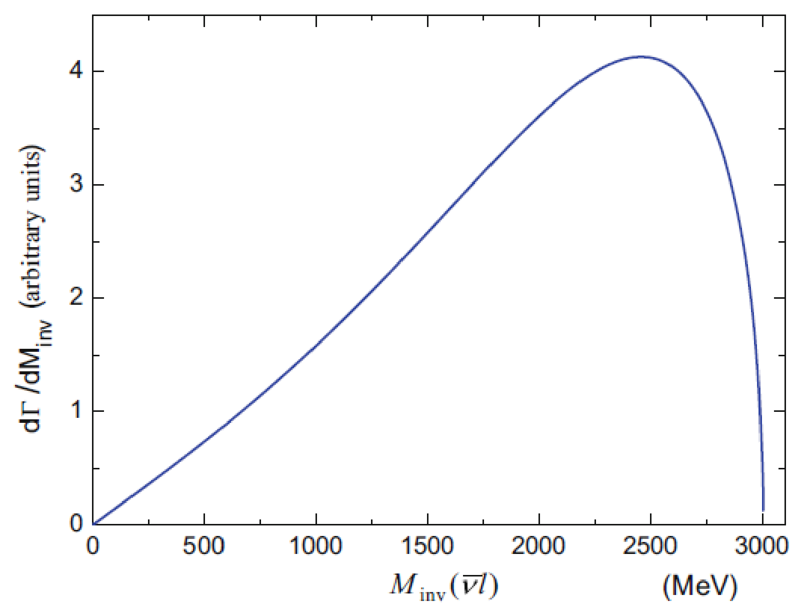


$$\frac{d\Gamma}{dM_{\rm inv}(\bar{\nu}_l l)} = \frac{M_{\Xi_c^*}}{M_{\Xi_b}} 2m_\nu 2m_l \frac{1}{(2\pi)^3} p_{\Xi_c^*} \tilde{p}_l \overline{\sum} \sum |t'|^2$$

$$\overline{\sum} \sum |t'|^2 = C'^2 \frac{8}{m_\nu m_l} \frac{1}{M_{\Xi_b}^2} \left(\frac{M_{\rm inv}}{2}\right)^2 \times \left[\tilde{E}_{\Xi_b}^2 - \frac{1}{3}\tilde{\vec{p}}^{\,2}_{\Xi_b}\right] A_J V_{\rm had}(J)$$

$$J = \frac{1}{2}:\ A_J V_{\rm had}(J) = \left|\frac{1}{2}\left(-\sqrt{\frac{3}{2}}\right) g_{R,\Sigma D}\, G_{\Sigma D} + \frac{1}{2}\frac{1}{\sqrt{6}} g_{R,\Lambda D}\, G_{\Lambda D} + \frac{1}{2\sqrt{3}}\left(-\sqrt{\frac{3}{2}}\right) g_{R,\Sigma D^*} G_{\Sigma D^*} + \frac{1}{2\sqrt{3}}\frac{1}{\sqrt{6}} g_{R,\Lambda D^*} G_{\Lambda D^*}\right|^2$$

$$J = \frac{3}{2}:\ A_J V_{\rm had}(J) = 2\left|\frac{1}{\sqrt{3}}\left(-\sqrt{\frac{3}{2}}\right) g_{R,\Sigma D^*}\, G_{\Sigma D^*} + \frac{1}{\sqrt{3}}\frac{1}{\sqrt{6}} g_{R,\Lambda D^*}\, G_{\Lambda D^*}\right|^2,$$



	$\Sigma\ D$	$\Sigma\ D^*$	$\Lambda\ D$	$\Lambda\ D^*$
g	$-1.178 - i0.101$	$0.777 + i0.285$	$-1.396 + i0.892$	$0.569 - i0.601$
gG	$6.544 + i0.239$	$-3.372 - i1.067$	$8.277 - i5.921$	$-2.45 + i2.844$

Values taken from Romanets , Tolos, Garcia-Recio, Nieves, Salcedo, Timmermans PRD 2012 reevaluated to get relative phases.

Table 2 Values of g and gG for the different channels for the resonance $\Xi_c^0(2790)(\frac{1}{2}^-)$

	$\Lambda\ D^*$	$\Sigma\ D^*$
g	$2.346 - i0.599$	$0.791 + i0.49$
gG	$-12.297 + i4.213$	$-4.148 - i2.15$

Table 3 Values of g and gG for the different channels for the resonance $\Xi_c^0(2815)(\frac{3}{2}^-)$

Predictions

$$R_1 = \frac{\Gamma_{\Xi_b \to \pi^- \Xi_c^0(2790)}}{\Gamma_{\Xi_b \to \pi^- \Xi_c^0(2815)}} = 0.384,$$

$$R_2 = \frac{\Gamma_{\Xi_b \to D_s^- \Xi_c^0(2790)}}{\Gamma_{\Xi_b \to D_s^- \Xi_c^0(2815)}} = 0.273$$

$$R_3 = \frac{\Gamma_{\Xi_b \to D_s^- \Xi_c^0(2790)}}{\Gamma_{\Xi_b \to \pi^- \Xi_c^0(2790)}} = 0.686,$$

$$R = \frac{\Gamma_{\Xi_b \to \bar{\nu}_l l\ \Xi_c(2790)}}{\Gamma_{\Xi_b \to \bar{\nu}_l l\ \Xi_c(2815)}} = 0.191.$$

Predictions of absolute rates:

$$\frac{BR(\Xi_b \to \pi^- \Xi_c^*)}{BR(\Lambda_b \to \pi^- \Lambda_c^*)} = \frac{M_{\Xi_c^*}}{M_{\Xi_b}} \frac{M_{\Lambda_b}}{M_{\Lambda_c^*}} \frac{q \overline{\sum} \sum |t|^2 \Big|_{\Xi_b}}{q \overline{\sum} \sum |t|^2 \Big|_{\Lambda_b}} \cdot \frac{\Gamma_{\Lambda_b}}{\Gamma_{\Xi_b}}$$

$$\frac{\Gamma_{\Lambda_b}}{\Gamma_{\Xi_b}} = \frac{\tau_{\Xi_b}}{\tau_{\Lambda_b}} = 1.08 \pm 0.19$$

$$BR[\Lambda_b \to \pi^- \Lambda_c(2595)] = \frac{(3.4 \pm 1.5) \times 10^{-4}}{BR[\Lambda_c(2595) \to \Lambda_c \pi^+ \pi^-]},$$

$$BR[\Lambda_b \to \pi^- \Lambda_c(2625)] = \frac{(3.3 \pm 1.3) \times 10^{-4}}{BR[\Lambda_c(2625) \to \Lambda_c \pi^+ \pi^-]},$$

$$BR[\Xi_b \to \pi^- \Xi_c(2790)] = (7 \pm 4) \times 10^{-6},$$

$$BR[\Xi_b \to \pi^- \Xi_c(2815)] = (13 \pm 7) \times 10^{-6},$$

$$BR[\Xi_b \to \bar{\nu}_l l\, \Xi_c(2790)] = \left(1.0^{+0.6}_{-0.5}\right) \times 10^{-4}$$

$$BR[\Xi_b \to \bar{\nu}_l l\, \Xi_c(2815)] = \left(3.3^{+1.8}_{-1.6}\right) \times 10^{-4}$$

Conclusions

In weak decays the consideration of the final state interaction of hadrons is essential to obtain decay rates

Very good source of information for the interaction of hadrons

One can minimize the input of the weak interaction if one looks at shapes of mass distributions, or at ratios of rates

In the examples that I showed, the sensitivity to the PB and VB components was huge, thus providing valuable information on the PB and VB components of some states which qualify as dynamically generated from the interaction of these components