DN interaction from meson exchange

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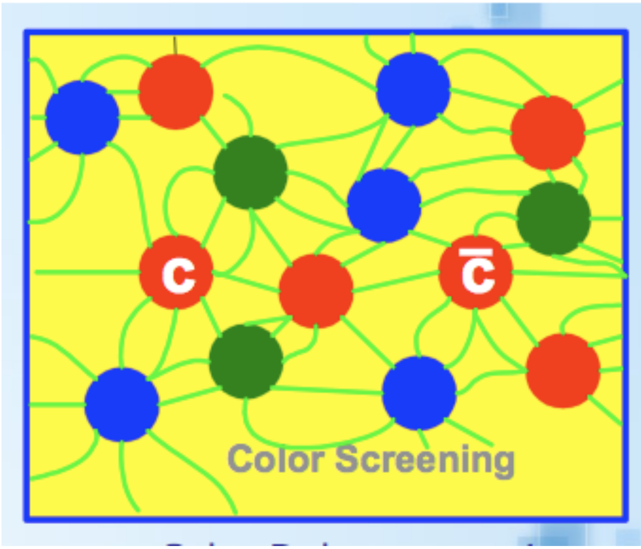
Outline

- Why studying DN interaction?
- DN interaction from meson-exchange (comparison with previous WT models)
- Discussion of the $\Lambda_c(2595)$ resonance
- Conclusions

Why studying DN interaction?

J/Ψ suppression

Gonin et al (NA50) ’96, Matsui and Satz ’86



taken from Hirano@CISS07

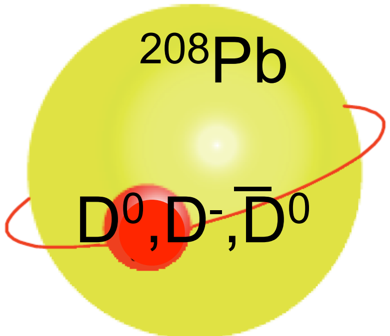
but also comover scattering

$$J/\Psi + (\pi, \rho) \rightarrow D + \bar{D}$$

Capella, Vogt, Wang, Bratkovskaya, Cassing, Andronic..

D-mesic nuclei

Tsushima et al ’99,
Garcia-Recio et al ‘10



DN interaction from meson-exchange

DN interaction built in close analogy to the Juelich meson-exchange K̄N model[1] using SU(4) symmetry and by exploiting the close connection between DN and D̄N[2] due to G-parity

- working hypothesis: SU(4) symmetry

$$g_{DD\rho} = \quad g_{DD\rho} = g_{KK\rho}$$
$$g_{DD\omega} = -g_{DD\omega} = g_{KK\omega}$$

- for scalar mesons (S=σ,a_0): $g_{\bar{D}\bar{D}S} \approx g_{KKS}$ but fine tune as well to get $\Lambda_c(2595)$

- form factors at M(=meson)MM vertices are taken over K̄N interaction

- most B(=baryon) BM vertices are the same as in K̄N ➔ taken over coupling constants and form factors. For those involving Λ_c and/or Σ_c SU(4) is invoked!

[1] Müller-Groeling al.,NPA 513 (1990) 557 (K^-N);
Hoffmann et al., NPA 593 (1995) 341(KN)
Hadjimichef, Haidenbauer, & Krein, PRC 66 (2002) 055214 (K^-N)
[2] Haidenbauer, Krein, Meißner & Sibirtsev, EPJA 33 (2007) 107

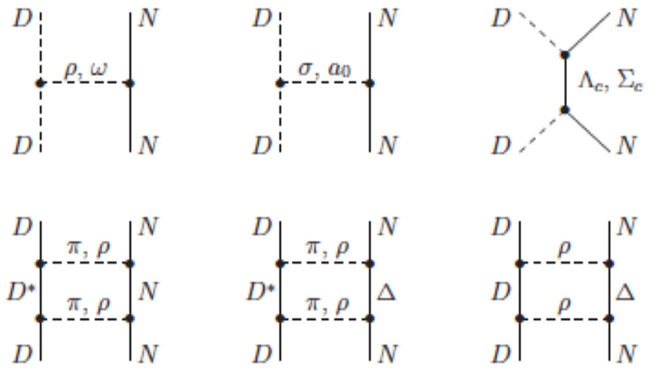


Fig. 1. Meson-exchange contributions included in the direct DN interaction.

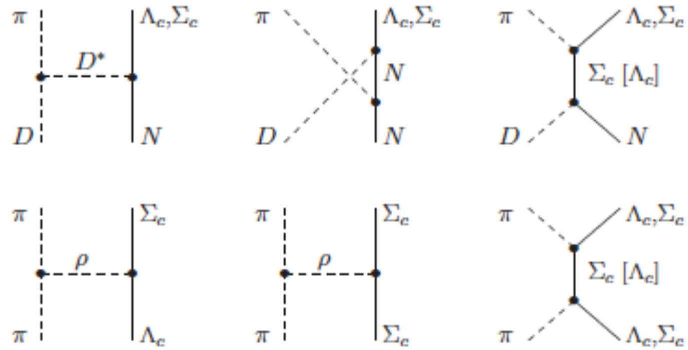


Fig. 2. Meson-exchange contributions included in the $DN \rightarrow \pi\Lambda_c, \pi\Sigma_c$ transition potentials and in the $\pi\Lambda_c, \pi\Sigma_c \rightarrow \pi\Lambda_c, \pi\Sigma_c$ interactions.

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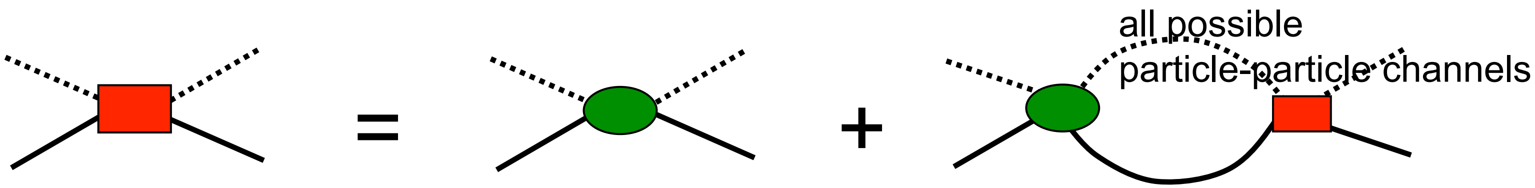
A bit of scattering theory…
….unitarized theory in coupled channels

S-matrix (collision operator)

final state after collision $|f> = S\, |i>$ initial state

S-matrix $S_{if} = \delta_{if} - i(2\pi)^4 \delta^4 (P_i - P_f) T_{if}$ scattering amplitude



$T_{if} = V_{if} + V_{il}\; G_l\; T_{lf}$

our model

Cross section

$$\sigma_{if} = \int (2\pi)^4 \frac{E_i \omega_i E_f \omega_f}{s} \frac{k_f}{k_i} \bar{\sum_i} \sum_\alpha |T_{if}|^2 d\Omega$$

experiment

theory

Scattering length

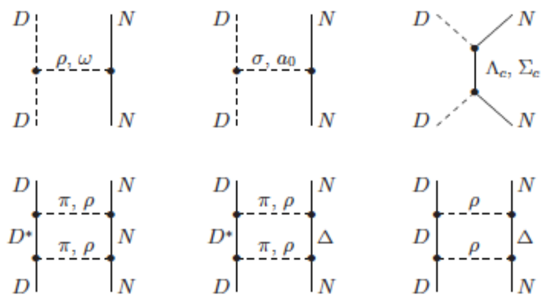
$$a_l = -(2\pi)^2 \frac{E\omega}{\sqrt{s}} \frac{T_l}{4\pi}$$

DN meson-exchange model
vs
DN TVME t->0 limit (WT)

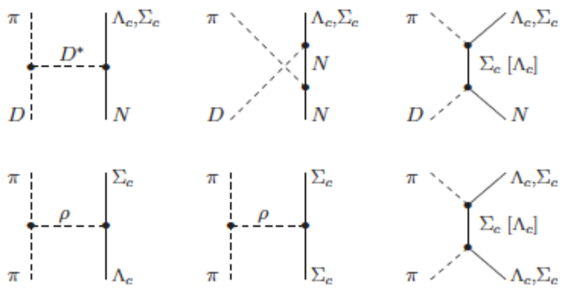
DN meson-exchange model

arXiv:1008.3794 [nucl-th]

DN-DN



DN->$\pi\Lambda_c,\pi\Sigma_c$; $\pi\Lambda_c,\pi\Sigma_c$->$\pi\Lambda_c,\pi\Sigma_c$



SU(4) WT model

Mizutani & Ramos, PRC 74 (2006) 065201

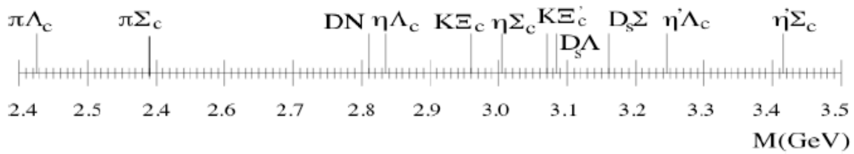
V built from the meson-baryon Lagrangian at lowest order

$$V_{ij} = -\kappa C_{ij}\frac{1}{4f^2}(2\sqrt{s}-M_i-M_j)\left(\frac{M_i+E}{2M_i}\right)^{1/2}\left(\frac{M_j+E'}{2M_j}\right)^{1/2}$$

SU(4) symmetry broken by the use of physical masses.

$$\kappa = 1 \quad \text{(non-charm exchange)} \quad DN\to DN,\ D_sY$$

$$= \left(\frac{m_\rho}{m_{D^*}}\right)^2 \sim 1/4 \quad \text{(charm exchange)} \quad DN\to \pi\Sigma_c,\ K\Xi_c$$



Implementation of HQSS: SU(8) WT model

Garcia-Recio et al., PRD 79 (2009) 054004

$$\mathcal{L}_{\rm WT}^{\rm SU(8)} = \left((M^\dagger\otimes M)_{63_a}\otimes(B^\dagger\otimes B)_{63}\right)_1$$

But SU(8) symmetry is strongly broken:

1.adopt physical hadron masses for kernel and thresholds

2.consider different weak non-charmed and charmed, as well as pseudoscalar and vector meson decay constants

Then, the SU(8) WT matrix elements in *IJSC* sector are

$$V_{ab}^{IJSC}(\sqrt{s}) = D_{ab}^{IJSC}\frac{2\sqrt{s}-M_a-M_b}{4\,f_a f_b}\sqrt{\frac{E_a+M_a}{2M_a}}\sqrt{\frac{E_b+M_b}{2M_b}}$$

with f the weak decay constant & M(E) the baryon mass (energy)

Results for DN model

SU(8) WT model differs significantly from the other two, but there is not a straightforward comparison because of the different regularization scheme and symmetry breaking. Moreover, the generalization of the Juelich model to include HQSS can lead to different results than SU(8) WT due to the exchange of more mesons

Scattering lengths and resonances

	meson-exchange model	SU(4) DN model	SU(8) DN model
scattering lengths [fm]			
$a_{I=0}$	$-0.41 + i\,0.04$	$-0.57 + i\,0.001$	$0.004 + i\,0.002$
$a_{I=1}$	$-2.07 + i\,0.57$	$-1.47 + i\,0.65$	$0.33 + i\,0.05$
pole positions [MeV]			
S_{01}	$2593.9 + i\,2.88$	$2595.4 + i\,1.0$	$2595.4 + i\,0.3$
S_{01}	$2603.2 + i\,63.1$	$2625.4 + i\,51.5$	$2610.0 + i\,35.5$
S_{01}		$2799.5 + i\,0.0$	$2821.5 + i\,0.5$
S_{01}			$2871.2 + i\,45.6$
S_{11}	$2797.3 + i\,5.86$	$2661.2 + i\,18.2$	$2553.6 + i\,0.34$
S_{11}		$2694.7 + i\,76.5$	$2612.2 + i\,89.5$
S_{11}			$2637.1 + i\,40.0$
S_{11}			$2822.8 + i\,17.4$
S_{11}			$2868.0 + i\,19.3$
P_{01}	$2804.4 + i\,2.04$		

Λ_c (2595)

Σ_c (2800)

Λ_c (2765)

DN->DN cross sections

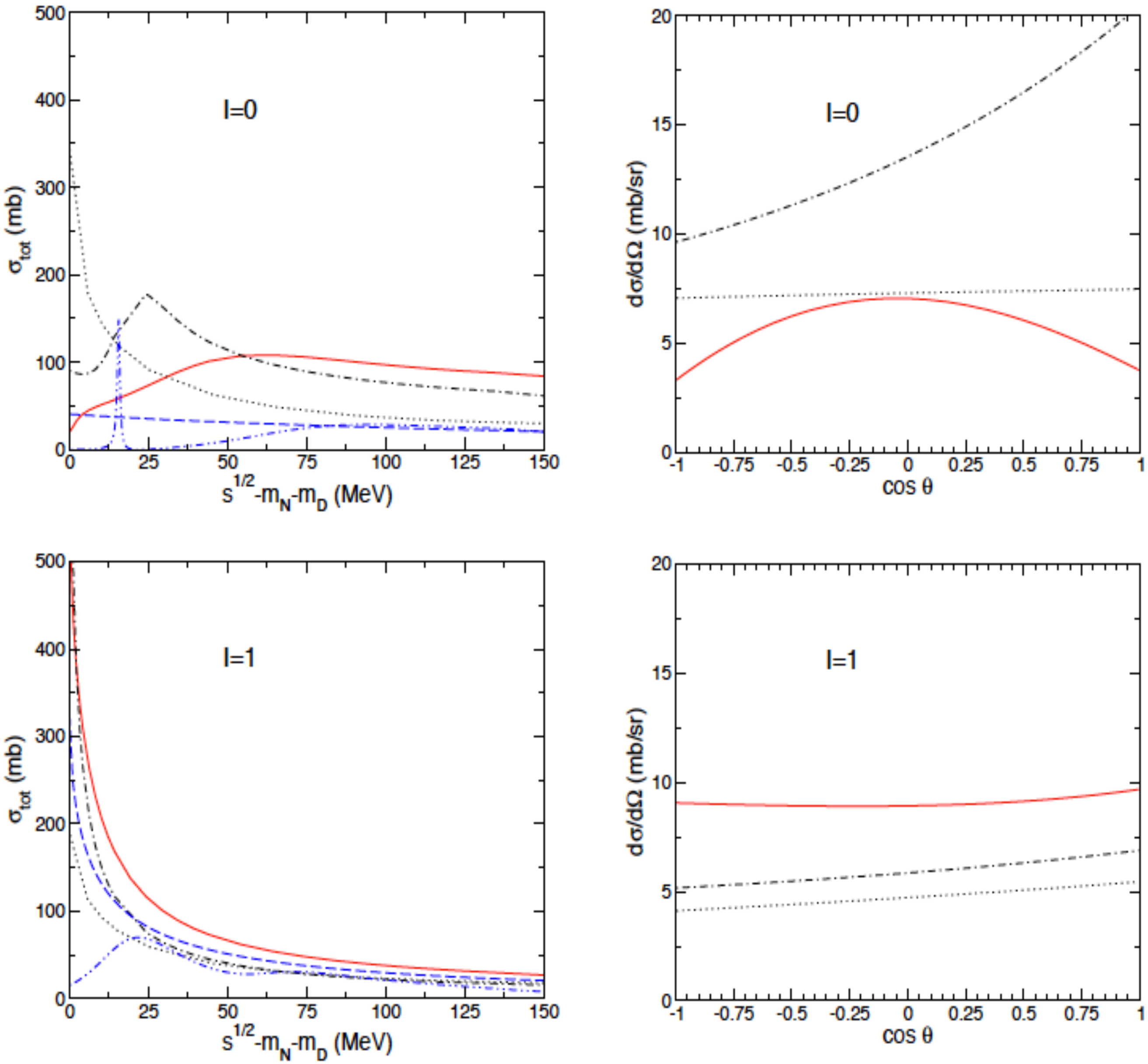
meson-exchange model

meson-exchange model based on parameters from KN and K^-N potentials

SU(4) WT model

SU(8) WT model

KN meson-exchange model



Discussion of the $\Lambda_c(2595)$

• $\Lambda_c(2595)$ was first observed by CLEO('95) and confirmed by E687('96) and ARGUS'97 as pronounced peak in the $\pi^+\pi^-\Lambda_c^+$ invariant mass distribution

• It is accepted as the charmed counterpart of the $\Lambda(1405)$, but several differences:

a) $\Lambda(1405)$ located close the $\bar{K}N$ threshold whereas $\Lambda_c(2595)$ coincides with $\pi\Sigma_c$
b) $\pi\Sigma$ and $\bar{K}N$ threshold are 100 MeV apart while $\pi\Sigma_c$ and DN are almost 200 MeV
c) $\pi\pi\Lambda$ at $\Lambda(1405)$ is barely open while $\pi\pi\Lambda_c$ opens 35 MeV below $\Lambda_c(2595)$

• A fine-tuning of inherent parameters reproduces the position of the $\Lambda_c(2595)$

• Experimental puzzle: $\Lambda_c(2595)$ decays dominantly into $\pi^+\Sigma_c^0$ and $\pi^-\Sigma_c^{++}$
While $M(\Lambda_c(2595))-M(\Lambda_c)$:

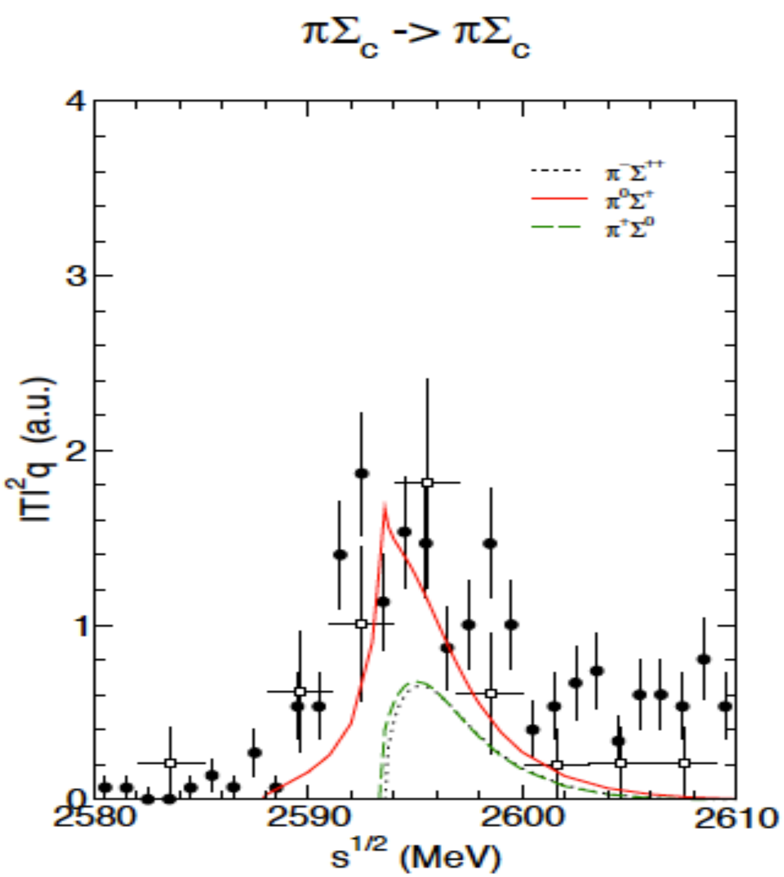
$$\begin{aligned}
&307.5 \pm 0.5 \pm 1.2 \quad \text{MeV [CLEO '95]},\\
&309.7 \pm 0.9 \pm 0.4 \quad \text{MeV [E687 '96]},\\
&309.2 \pm 0.7 \pm 0.3 \quad \text{MeV [ARGUS '97]},
\end{aligned}$$

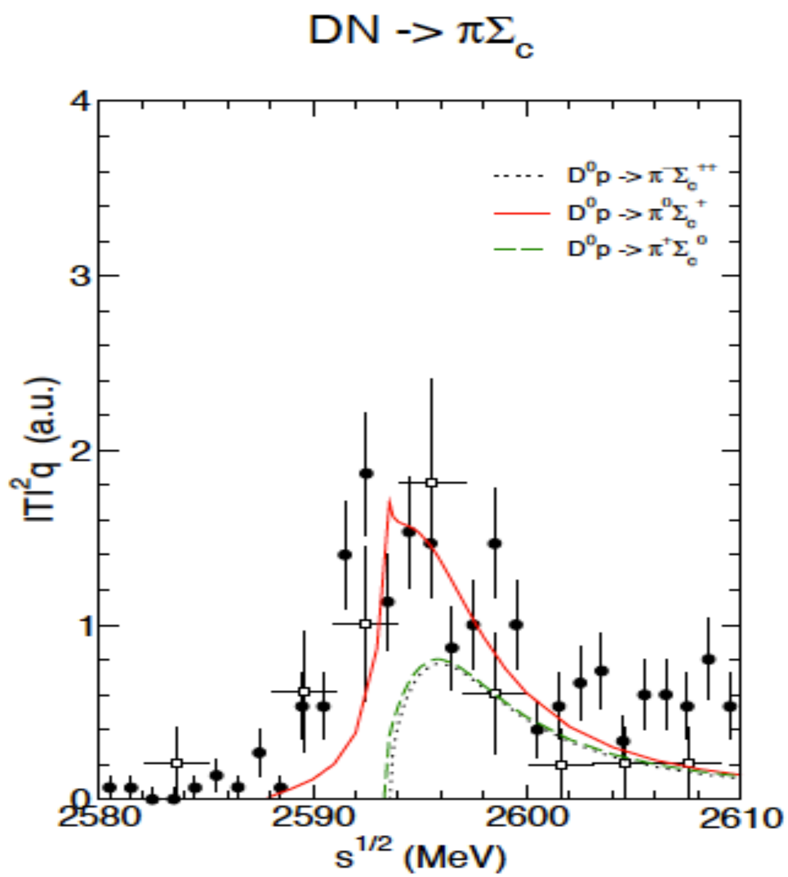
and

$$\begin{aligned}
M(\pi^-) + M(\Sigma_c^{++}) - M(\Lambda_c) &= 307.13 \pm 0.18 \text{ MeV},\\
M(\pi^0) + M(\Sigma_c^{+}) - M(\Lambda_c) &= 301.42 \pm 0.4 \text{ MeV},\\
M(\pi^+) + M(\Sigma_c^{0}) - M(\Lambda_c) &= 306.87 \pm 0.18 \text{ MeV},
\end{aligned}$$

A new measurement of CLEO('99) $305.3 \pm 0.4 \pm 0.6$ MeV [CLEO '99]

No phase space for $\Lambda_c(2595)$ decay into $\pi^+\Sigma_c^0$ and $\pi^-\Sigma_c^{++}$!! Only due to Σ_c widths ??





- Results resemble very much the measured signal and smearing them out by the width of Σ_c^+ (4 MeV) would yield to a good fit

- But $\Lambda_c(2595)$ decays dominantly into $\pi^+\Sigma_c^0$ and $\pi^-\Sigma_c^{++}$ and widths of Σ_c^0 and Σ_c^{++} are only 2 MeV ➔ many event unexplained!!!

- Need of $\pi^+\pi^-\Lambda_c^+$ channel but also confirm new CLEO('99) data

Conclusions

- We present a model for the interaction in the coupled systems DN, $\pi\Lambda_c$ and $\pi\Sigma_c$, developed in close analogy to the meson-exchange $\bar{K}N$ interaction of the Juelich group, using SU(4) symmetry constraints.

- The interaction generates several states dynamically: S_{01} $\Lambda_c(2595)$, S_{11} (2797) to be identified with $\Sigma_c(2800)$ and $P_{01}(2804)$ to be $\Lambda_c(2765)$

- Results for DN scattering lengths and cross sections are compared to other schemes based on TVME in the t->0 limit (WT). While there is a fairly good agreement between our model and the SU(4)WT, the different resonant structure of the SU(8) WT gives drastically different results

- We discuss the $\Lambda_c(2595)$ resonance pointing out the necessity of including the $\pi^+\pi^-\Lambda_c^+$ channel but also the need of reviewing the experimental CLEO'99 data