Associative photo- and electro-production of charmed particles near threshold

Reaction			Threshold [GeV]
$(\gamma^*)\gamma + p$	$\to$	$\Sigma_c^{++} + D_c^-$	9.4856
	$\to$	$\Sigma_c^{+} + D_c^0,$	9.4676
	$\to$	$\Lambda_c^{+} + D_c^0,$	9.4676
$(\gamma^*)\gamma + n$	$\to$	$\Lambda_c^{+} + D_c^0,$	8.7064
	$\to$	$\Sigma_c^{+} + D_c^-$	10.1286
	$\to$	$\Lambda_c^{+} + D_c^-$	10.1286
	$\to$	$\Sigma_c^{++} + D_c^{*-}$	10.1286

Particle	Mass [GeV]
$\Sigma_c^{++} = uuc$	2.4528
$\Sigma_c^{+} = (ud)_{I=1}c$	2.4536
$\Lambda_c = (ud)_{I=0}c$	2.2849
$\underline{D_c^-} = \overline{c}d$	1.8693
$\overline{D_c^0} = \overline{c}u$	1.8646
$\overline{D_c^-} = \overline{c}d$	1.8693
$\overline{D_c^{*-}} = \overline{c}d \; I(\mathcal{J}^P) = \frac{1}{2}(1^-)$	2.0067

- *Near threshold physics (similar to the physics of photo- and electro-production of pions and strange particles).*

- *Large masses of the produced particles: $\to$ possible applicability of perturbative QCD, even in threshold conditions.*

- *Possibility to determine the* **magnetic moments** *of charmed baryons and specific interaction constants.*

Effective Lagrangian approach

- *Photoproduction:*

  Calculation of cross section → electromagnetic vertex-strong vertex (constants: $g(N\overline{D}\Lambda_c)$, $g(N\overline{D}\Sigma_c)$, magnetic moments of charmed particles)

$$\sigma(\gamma p \to \overline{D}\Sigma_c^{++}) : \sigma(\gamma p \to \overline{D}^0\Sigma_c^{+}) : \sigma(\gamma n \to D^-\Sigma_c^{+}) : \sigma(\gamma n \to \overline{D}^0\Lambda_c)$$

$$34 \qquad\qquad 6 \qquad\qquad 1 \qquad\qquad 17$$

  using a simple prescription for the magnetic moments derived from U(4)-symmetry.

- *Electroproduction:*

  Calculation of cross section for $k^2 \simeq 0.1 - 0.2$ GeV^2:

  The amplitude can be expressed as simple function of the ratio of the charmed particle and the nucleon radius :

$$\sigma(\gamma^* n \to \overline{D}^0\Sigma_c^0) = \frac{eg}{8\pi W}\sqrt{\frac{M_{\Sigma_c}}{W}}\left[4.6 + 2.8k^2\left(3.4 + 0.8\frac{r_2^2(\Lambda_c)}{r_N^2}\right)\right]$$

Simple estimation of the possible cross section

$$\frac{1}{g^2_{N\Sigma D}}\sigma(\gamma p \to \Sigma_c D) \simeq \frac{\alpha}{M^2}\frac{q}{k}$$

$M \simeq 2.5$ *GeV : mass of* Σ_c *or* D,

$g_{N\Sigma D}$ *: constant for* $N\Sigma_c D_c$*-vertexes,*

q *and* k *: final and initial 3-momenta.*

$\sigma(\gamma p \to \Sigma_c D)/g^2_{N\Sigma D} \simeq 10^{-2}\cdot 10^{-28}\ cm^2 \cdot 10^{-1} \simeq 10^{-31}\ cm^2.$

Assuming a luminosity $\mathcal{L} = 10^{34}\ cm^{-2}s^{-1}$ *the counting rate, is:* $N = \sigma \cdot \mathcal{L} \simeq 10^3$ *particles/s, i.e.* $\simeq 10^{10}$ *per year.*

Photoproduction processes of charmed particles with charm nonconservation

Reaction	*Threshold [GeV]*
$\gamma + p \to \Sigma_c^{++} + K^0$	4.1724
$\to \Sigma_c^0 + K^+,$	4.1554
$\to \Lambda_c^+ + K^0,$	3.6569
$\gamma + n \to \Sigma_c^0 + K^0$	4.1609

- *Simultaneous violation of conservation of charm and strangeness.*

- *Weak interaction without Cabibbo suppression*

Simple estimation of the possible cross section

$$\sigma \simeq \alpha G^2 M^2 \simeq 10^{-40}\ cm^2$$

G: *Fermi constant,*

M : *nucleon mass,*

α: *constant of electromagnetic interaction.*

Conclusions

- *Estimation of cross section, in the effective Lagrangian approach, for the following processes:*
  - *associative charmed particle photo- and electro-production*

$$\begin{aligned}
(\gamma^*)\gamma + p &\to \Sigma_c^{++} + D_c^-, \\
&\to \Sigma_c^{+} + D_c^0, \\
&\to \Lambda_c^{+} + D_c^0, \\
&\to \Sigma_c^{++} + D_c^{*-}
\end{aligned}$$

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  - *processes with simultaneous violation of conservation of charm and strangeness.*

$$\begin{aligned}
\gamma + p &\to \Sigma_c^{++} + K^0 \\
&\to \Sigma_c^{0} + K^+, \\
&\to \Lambda_c^{+} + K^0, \\
\gamma + n &\to \Sigma_c^{0} + K^0
\end{aligned}$$

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- *Update and complete these calculations, (values of masses, magnetic moments, angular distributions...)*