# Photoproduction of $\Theta^+$ in $\gamma + D \to \Lambda + \Theta^+$ and $\gamma + D \to \Sigma + \Theta^+$ reactions

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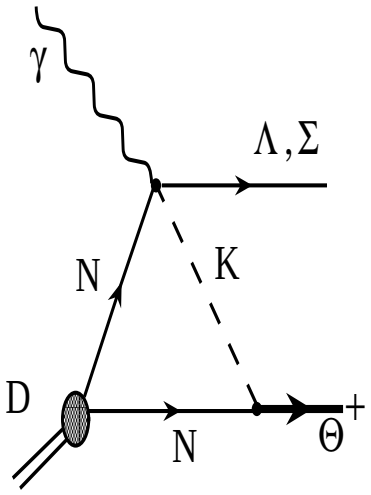
1. Motivation
2. Calculation and results
3. Interference with BG
4. $\Theta^+$ of isospin-1
5. Conclusions and discussion

## Motivation

- Suggest novel $\Theta^+$ production reaction that can be estimated with little model dependence

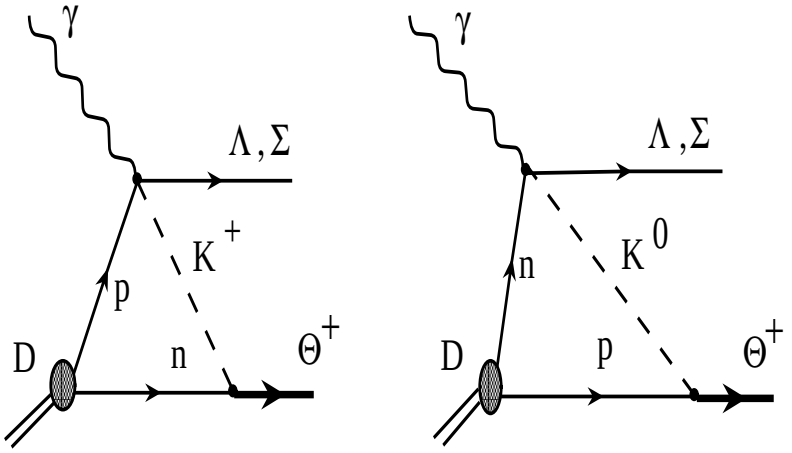



In SPring-8 and CLAS experiments, nuclear effects are contamination; here rescattering on the spectator nucleon is necessary to produce $\Theta^+$.

- Cross section proportional to $\Gamma_\Theta^{\rm tot} \to$ means to determine the total width of $\Theta^+$

## Calculations

- There are two Feynman diagrams

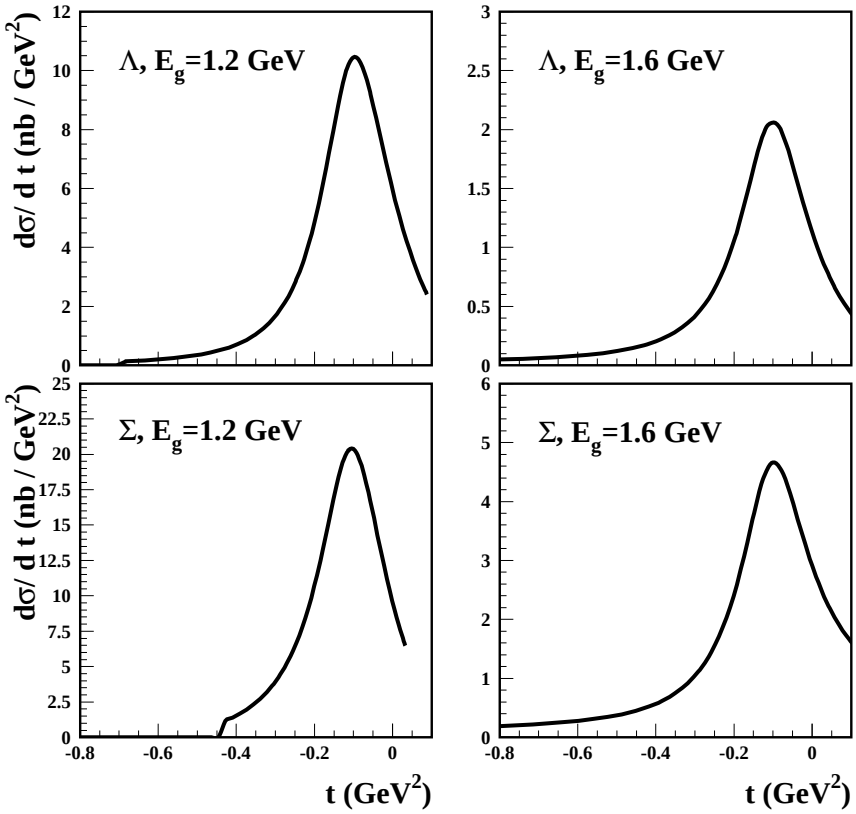



Assume that imaginary part dominates. This is equivalent to all particles being on or near mass shell.

- Cross section factorizes into 3 factors

$$\frac{d\sigma^{\gamma+D\to\Lambda(\Sigma)+\Theta^+}}{dt} = \Gamma_\Theta^{\rm tot} f(\text{Masses}) \times \frac{d\sigma^{p+n}}{dt} \times S(t)$$

## Results




$t$-dependence is mostly determined by nuclear suppression factor $S(t)$. Most favorable region: $-0.2 < t < 0$ GeV$^2$.

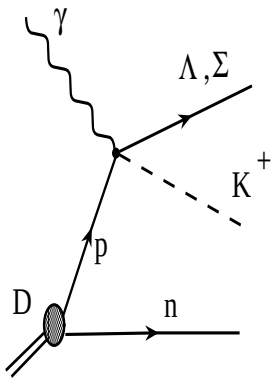
- Energy dependence is steep and is determined by $d\sigma^{p,n}/dt$ and their interference.

- Cross section integrated over $t$ assuming $\Gamma_\Theta^{\rm tot} = 5$ MeV.

| $E_\gamma$, GeV | $\sigma^{\gamma+D\to\Lambda+\Theta^+}$, nbarn | $\sigma^{\gamma+D\to\Sigma+\Theta^+}$, nbarn |
|---|---|---|
| 1.2 | 2.51 | 4.44 |
| 1.6 | 0.57 | 1.42 |

## Background and its interference with signal

- There is very large BG reaction




The experiment measures Signal+Interference+BG

- Can be separated by measuring spectator nucleon in coincidence

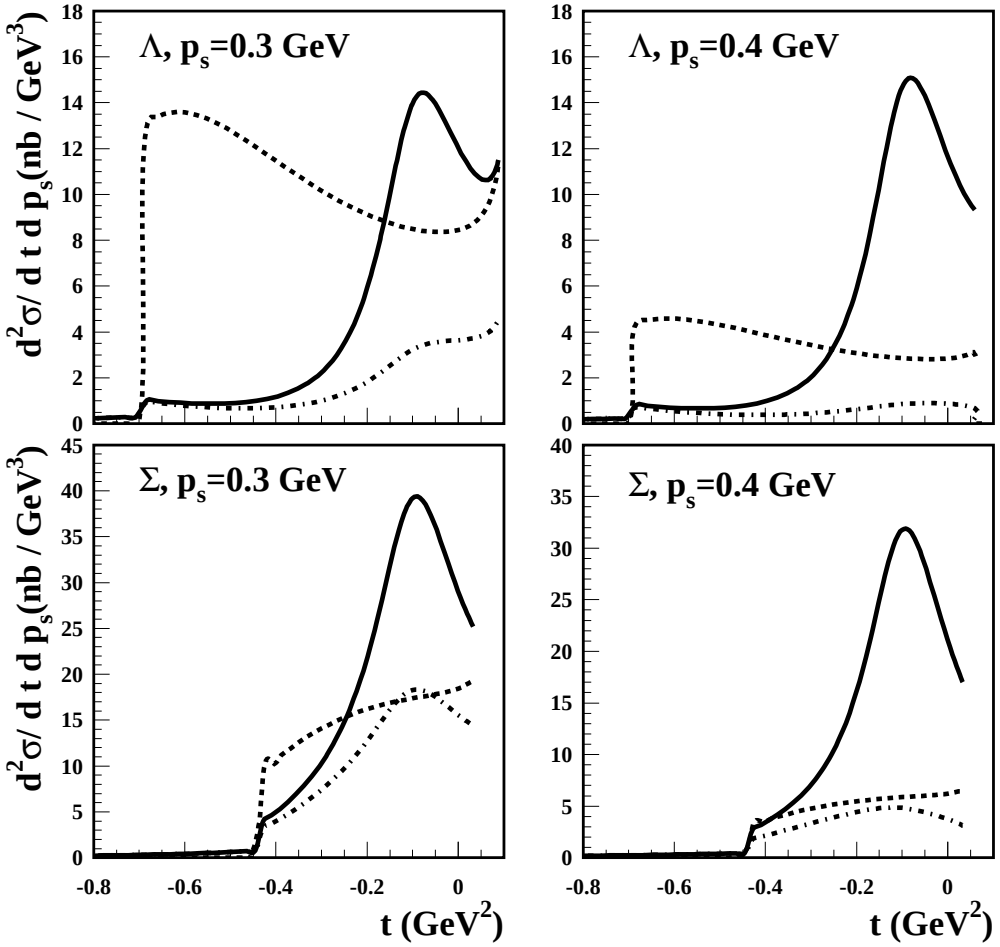
$$\text{Signal} \propto nK \,\text{phase space}$$

$$\text{Interference} \propto \psi_D(p_s)$$

$$\text{BG} \propto |\psi_D(p_s)|^2$$

- BG can be suppressed by choosing sufficiently large $p_s$: $p_s > 300$ MeV/c and
by requiring that $|M_\Theta - M_{nK^+}| < \epsilon = 10$ MeV.

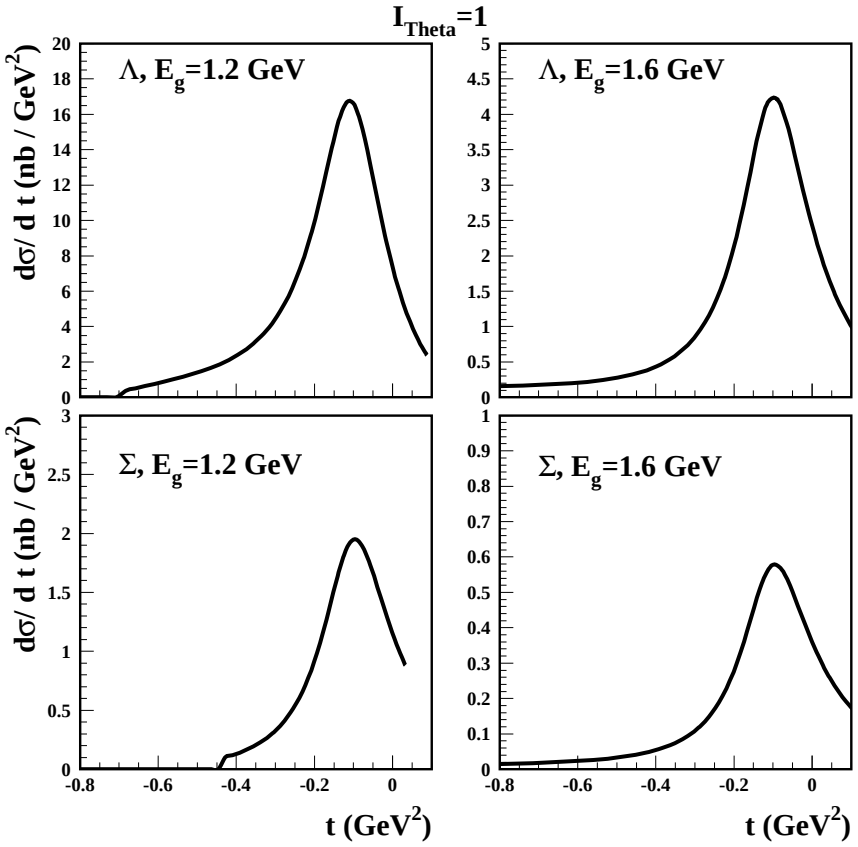
# Signal, Interference and Background



## $\Theta^+$ with isospin-1

$$\mathcal{L}^{I=0}_{\Theta^+ NK} \propto \Theta^+ \bar{N} K$$
$$\mathcal{L}^{I=1}_{\Theta^+ NK} \propto \Theta^+ \bar{N} \tau^3 K$$

- This introduces a minus sign between the two Feynman diagrams and changes results dramatically




- Production of $\Lambda\Theta^+$ becomes larger than $\Sigma\Theta^+$.

## Conclusions and discussion

- Photoproduction of $\Theta^+$ in $\gamma + D \to \Lambda + \Theta^+$ and $\gamma + D \to \Sigma + \Theta^+$ reactions can be estimated with little model dependence
- Cross section is proportional to $\Gamma_\Theta^{\rm tot} \to$ reliable method to determine the width of $\Theta^+$.
- Cross section of order several nbarn at $\Gamma_\Theta^{\rm tot} = 5$ MeV.
- Comparison of $\Lambda\Theta^+$ and $\Sigma\Theta^+$ gives unambiguous method to establish isospin of $\Theta^+$.
- The result is the same for positive and negative parity of $\Theta^+$. In general, the proposed reactions do not seem good candidates to determine parity of $\Theta^+$.