Hypernuclear Production with Hadronic and Electromagnetic Probes

## **Radhey Shyam**

#### Saha Institute of Nuclear Physics, Kolkata, India Z.Zt. Institut f. Theo. Physik, Uni Giessen, Germany

#### PLAN OF THE PRESENTATION

- 1. Introduction Production of Hypernuclei
- 2. Brief sketch of the theoretical model
- 3. Results, cross sections, spectroscopy
- 4. Conclusions

Coll. U. Mosel, H. Lenske, S. Bender

# **Production of \Lambda Hypernuclei**

# (K<sup>-</sup>, $\pi$ <sup>-</sup>) reaction

 $K^{-} + n \rightarrow \Lambda + \pi^{-}$ 

Strangeness exchange

$$K^{-}_{stopped}$$
 +  $^{A}Z \rightarrow ^{A}_{\Lambda}Z$  +  $\pi^{-}$ 

( $\pi^+$ , K<sup>+</sup>) reaction

- ( $\gamma$ , K<sup>+</sup>) reaction
- (e, e' K<sup>+</sup>) reaction

(p, K<sup>+</sup>) reaction

- $\pi^+ + n \rightarrow \Lambda + K^+$
- $\gamma + p \rightarrow \Lambda + K^+$
- $\gamma^* + p \rightarrow \Lambda + K^+$
- $p + p \rightarrow p + \Lambda + K^+$

Associated strangeness production

Momentum Transfer in various reactions on a <sup>12</sup>C Target



#### (p,K<sup>+</sup>) reaction

momentum transfers are much large nuclear bound state wave functions are sampled in regions not reached in other reactions.

#### ( $\pi^+$ , K<sup>+</sup>) and ( $\gamma$ , K<sup>+</sup>) reactions

Momentum transfer larger than the Fermi momentum $\rightarrow$ (n-hole,  $\Lambda$ -particle) configuration in a series of orbits (even deepest one)

Stretched states with maximum spin are preferentially excited.

#### (K<sup>-</sup>, $\pi$ <sup>-</sup>) reaction

Low momentum transfer at forward angles ⇒ only substitutional states are populated.

(y, K+) and (e,e'K<sup>+</sup>) reactions can also excite unnatural parity stretched states

#### Amplitudes for various reactions



**Target emission** 

**Α (p,K<sup>+</sup>)<sub>Λ</sub>B** 





#### **π (p,K<sup>+</sup>)<sub>Λ</sub>B**

γ (p,K<sup>+</sup>)<sub>Λ</sub>B

## A Covarient Description of A(h $\gamma$ ,K<sup>+</sup>)<sub>A</sub>B reaction

- **Effective Lagrangians at various vertices**
- Bound state nucleon and hyperon spinors
- Initial and final state interactions (distorted waves).
- Self energies for intermediate resonances (also for Intermediate mesons in proton induced reactions)

### **Bound Hypernuclear wave function**



Pure single particle configuration with core remaining inert In the region of the momentum transfer of interest, the lower component of the spinor is not negligible.

#### **Description of the A(p,K<sup>+</sup>)**<sub> $\Lambda$ </sub>**B reaction**

**Thresholds** for the  $A(p,K+)_A B$  reaction depends on the target mass.



Effective Lagrangian Model describes the pp  $\rightarrow$  pAK<sup>+</sup> reaction well R. Shyam, Phys. Rev. C 60 (1999) 055213, C73 (2006) 035211

Excitation of N<sup>\*</sup> (1650), N<sup>\*</sup> (1710), N<sup>\*</sup> (1720) baryonic resonances.



R. Shyam, H. Lenske and U. Mosel, Nucl. Phys. 764 (2006) 313

### Application to the ( $\pi^+$ , K<sup>+</sup>) reaction on Nuclei

S. Bender



N\*(1710) dominates in this case too.

# **SUMMARY AND OUTLOOK**

- Hypernuclei can be produced by  $A(h \gamma, K^+)_{\Lambda}B$  reactions, which are different ways of studying such systems.
- A fully covariant description of these reactions is essential.
- Hypernuclear states with low binding energies are preferentially excited.
- Differences in the angular distributions of the reaction on very light and heavier targets.
- (γ, K+) and (e,e'K<sup>+</sup>) reactions can also excite unnatural parity stretched states, an added attraction. WORK IS IN PROGRESS ON THESE REACTIONS.