Structure and production of *p*-shell Ξ-hypernuclei
($^{12}_{\Xi}$Be)

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Introduction

- Up to now, the experimental information are limited for Ξ hypernuclei as compared to Λ hypernuclei.
- Theoretically, a pioneer work was done by Dover and Gal (Ann. Phys. **146** (1983)) using the existent data at that time.
- The experiments using the (K^-,K^+) reaction were performed at KEK (Aoki et al. PLB **355** (1995), Fukuda et al. PRC **58** (1998)) and BNL (Khaustov et al. PRC **61** (2000)). But a definite evidence of the existence of the Ξ hypernuclei was not obtained.
  - U_Ξ~-14~-17MeV (Shallow)
- At JPARC, the experiment of the (K^-,K^+) reaction with high intensity is planned to explore Ξ hypernuclei.

Doorway to the physics of S=-2!

Purpose of our study

- Studying the structure of Ξ hypernuclei using the shell model with effective interactions deduced from realistic NΞ interaction models.
- Performing a reaction calculation with the wave functions of the shell model to explore what we can obtain from the experimental data.
- We want to deduce the information about the NΞ interaction from the forthcoming experiment of Ξ hypernuclei.
  - Strength
  - Spin dependence
  - Isospin dependence (T=0 and T=1)

This method has been quite successful in the study of Λ hypernuclei!

Shell model calculation

- $^{12}_{\Xi}Be$ ($^{11}B+\Xi^-$) ($^{12}C(K^-,K^+)^{12}_{\Xi}Be$)
- Active space for nucleons: *p*-shell orbits
- Acitev space for Ξ: $0s_{1/2}$ and $1s_{1/2}$ orbits
- Effective interaction for nucleons: Cohen-Kurath
- Effective interaction for *N*-Ξ: YNG-type interaction by Yamamoto (*G* matrix, k_F dependence)
  - YN interaction model ($V_{N\text{-}\Xi}$: attracitve)
    - NHC-D (Nagels et al. PRD **15** 2547 (1977))
    - ESC04d (Rijken and Yamamto PRC **73** 044008 (2006))
    - Ehime (Yamaguchi et al. PTP **106** 627 (2001))
  - Non-central and Coulomb parts are not included.

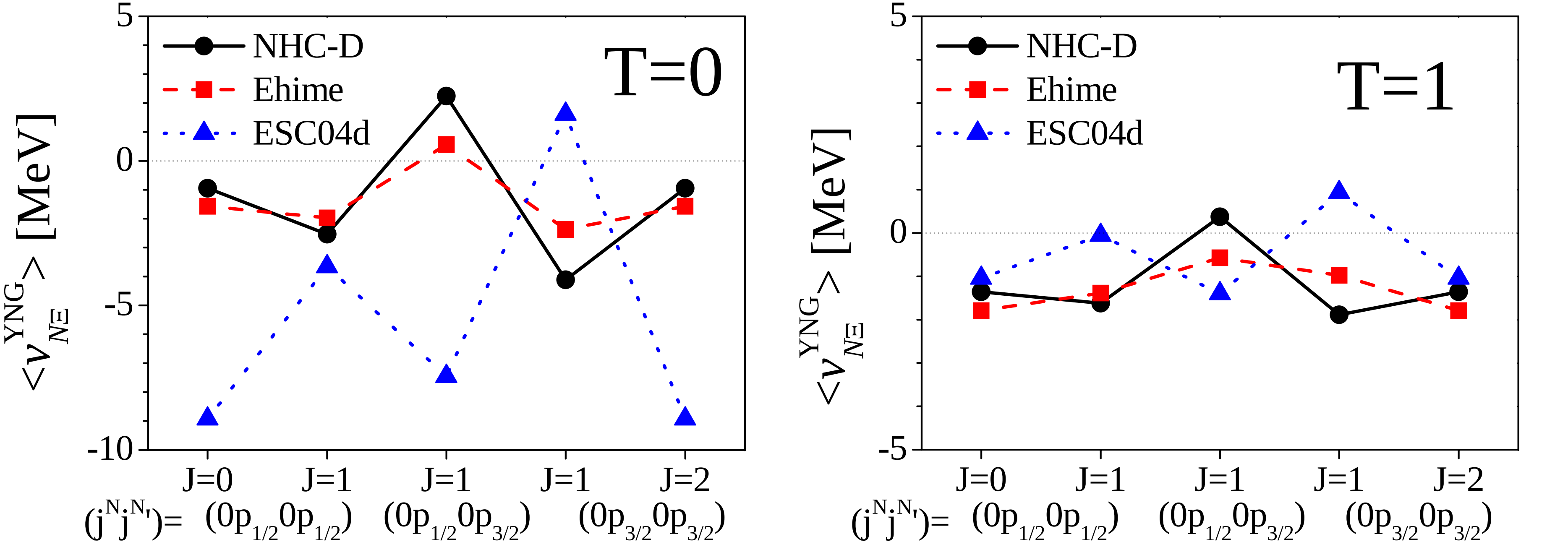
$$H_{NY} = \underbrace{H_N}_{\text{CK}} + \underbrace{t_Y + v_{NY}}_{\text{YNG}}$$

Single particle energy $^{12}_{\Xi}Be$

	J^π	T	k_F	t_Y	U_Y	t_Y+U_Y
NHC-D(Ξ)	1^-_1	1	1.05	11.8	-15.3	-3.5
Ehime(Ξ)	1^-_1	1	0.84	10.5	-15.1	-4.5
ESC04d (Ξ)	1^-_1	1	1.08	11.8	-16.1	-4.4
NS97f(Λ)	1^-_1	1/2	1.24	10.5	-22.5	-11.9

- k_F in YNG is determined by the condition BE($\Xi, 1^-_1$)~4.5 MeV.
- U_Ξ is comparable to the experimental data. U_Ξ ~ -14~-17MeV (Aoki et al. and Yamamoto, Fukuda et al. and Ikeda et al., Khaustov et al.)

p-shell matrix element (ΞN)



$$\left\langle j^N 0s_{1/2}^{\Xi} \left| v_{N\Xi}^{YNG} \right| j^{N'} 0s_{1/2}^{\Xi} \right\rangle_{JT}$$

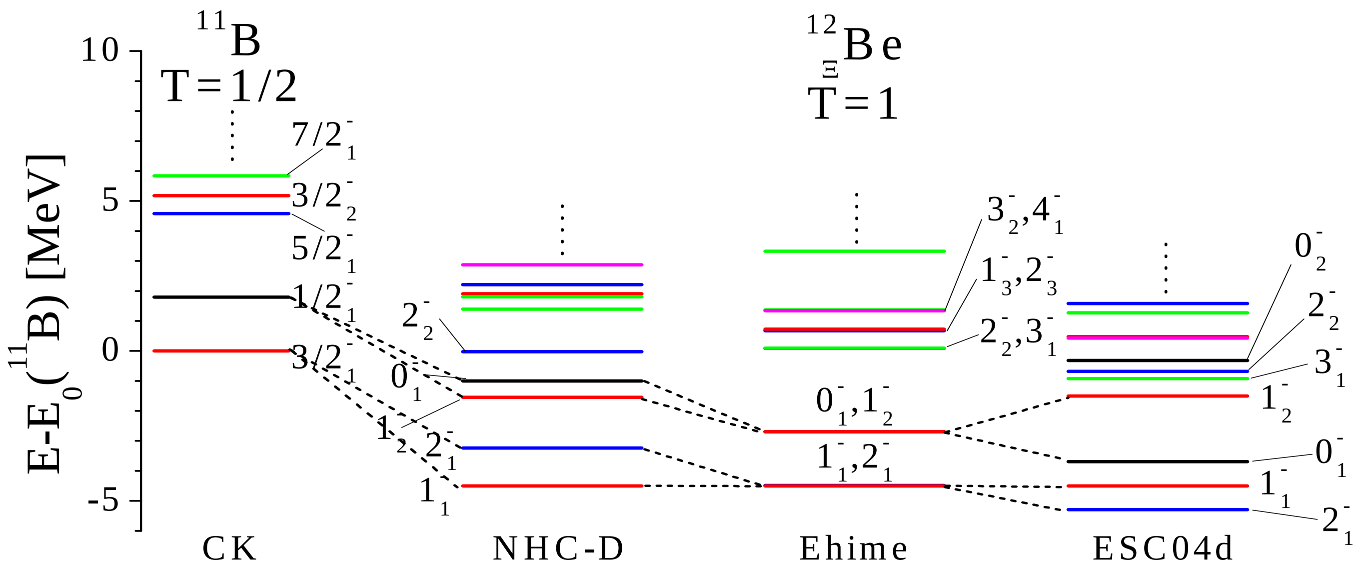
Spin and isospin dependence of the ΞN interactions

$$V_{NY} \sim -\bar{V} + \Delta \sigma \cdot \sigma$$

	T	Vb	Δ(σ·σ)	η (Δ/Vb)
N-Ξ NHC-D	0	2.14	4.75	2.23
	1	1.55	0.79	0.51
N-Ξ Ehime	0	1.87	1.20	0.64
	1	1.49	-1.22	-0.82
N-Ξ ESC04d	0	4.98	-15.81	-3.18
	1	0.30	-2.96	-9.88
N-Λ NSC	1/2	1.36	1.16	0.86

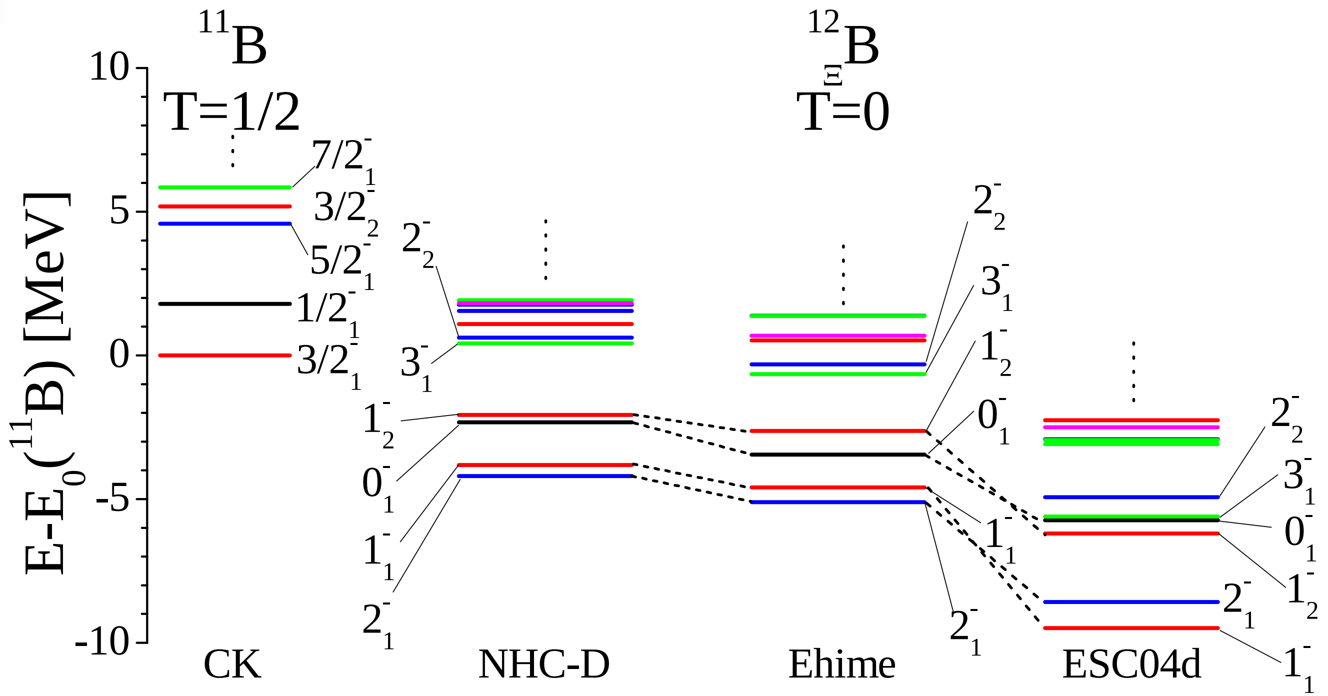
- Δ for N-Ξ is larger than that for N-Λ.
- ESC04d gives large Δ.
- Δ for ESC04d and NHC-D have opposite signs.

T=1 states



- NHC-D: Vσσ(T=1) and Vσσ(T=0) are added up coherently
- Ehime: Vσσ(T=1) and Vσσ(T=0) cancel out
- ESC04d: Vσσ (T=1) and Vσσ (T=0) are added up coherently, but the sign is opposite to ones for NHC-D

T=0 states



- The binding energies of the T=0 states for ESC04d is larger than those in the T=1 state by about 5MeV.
- It is interesting to study the isospin dependence of the NΞ interaction.

DWIA cal. $^{12}C(K^-,K^+)^{12}{}_{\Xi^-}Be$

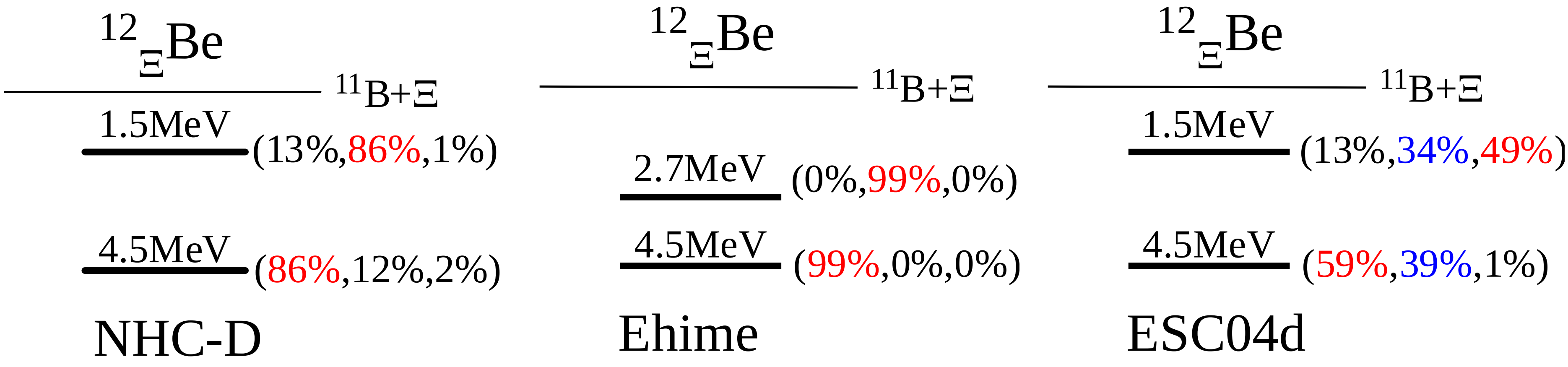
- We calculated the effective proton number in the DWIA approximation.

$$\frac{d\sigma(\theta)}{d\Omega_L} = \alpha \left[\frac{d\sigma(\theta)}{d\Omega_L} \right]_{K^- p \to \Xi^- K^+} Z_{\text{eff}}^{\text{SM}}(i \to f;\theta)$$

- (K^-,K^+) reaction
  - Large momentum transfer （~500MeV/c@p_{K-}=1.7GeV/c) ->J-stretched states are populated strongly.
  - Isospin transfer 1 (p(t_z=1/2->Ξ^-(t_z=-1/2))

$$[0p^{-1}\Xi 0s]_{J^\pi=1^-,T=1}$$

T=1, 1^- state in $^{12}_{\Xi}$Be



$(P(^{11}B(3/2^-_1)\otimes\Xi 0s_{1/2}), P(^{11}B(1/2^-_1)\otimes\Xi 0s_{1/2}), P(^{11}B(3/2^-_2)\otimes\Xi s0_{1/2}))$

- In the $^{12}C(K^-,K^+)^{12}_{\Xi}Be$ reaction, T=1,1^- states are strongly populated.
- Wave functions strongly depend on the N-Ξ interaction.

Excitation Function NHC-D

$^{12}{}_{\Xi}$Be

^{11}B+Ξ

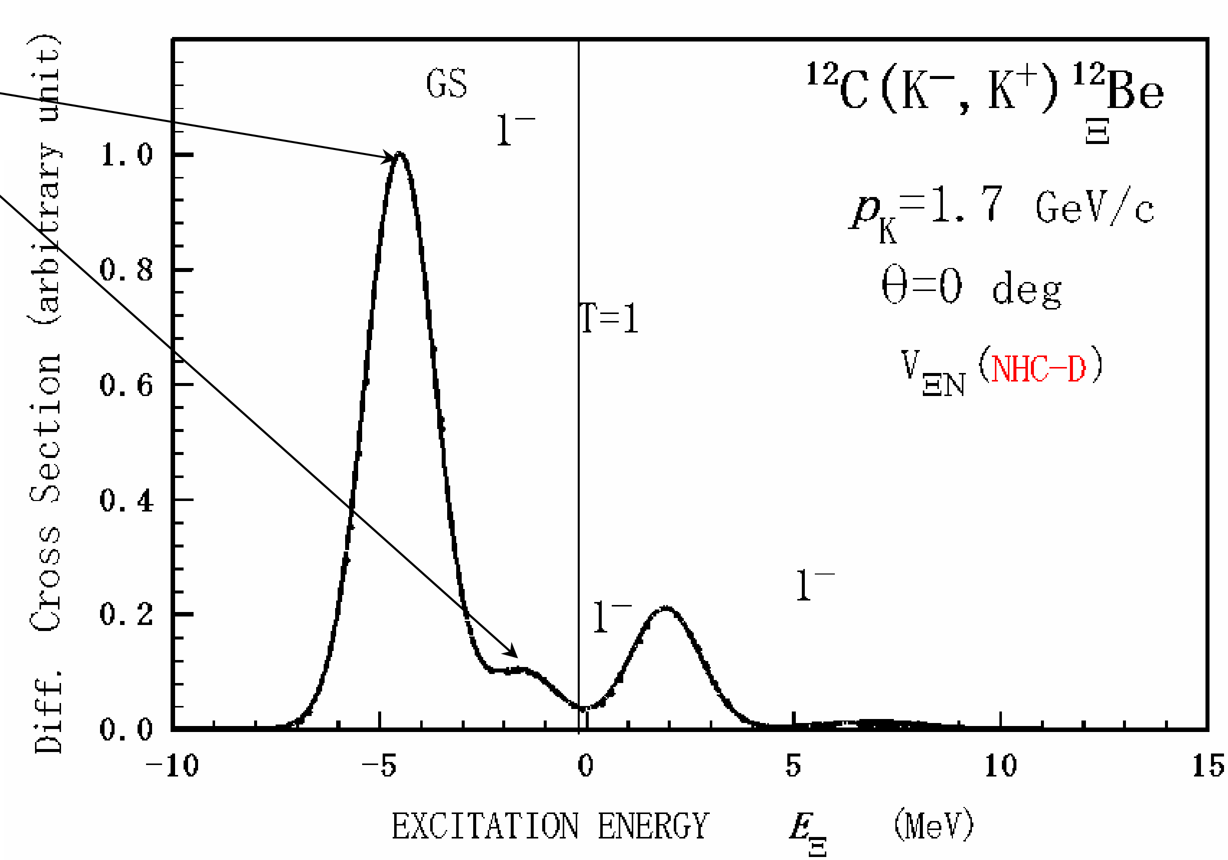
1.5MeV (13%,86%,1%)

4.5MeV (86%,12%,2%)

NHC-D

σ_{max}=0.13μb/sr

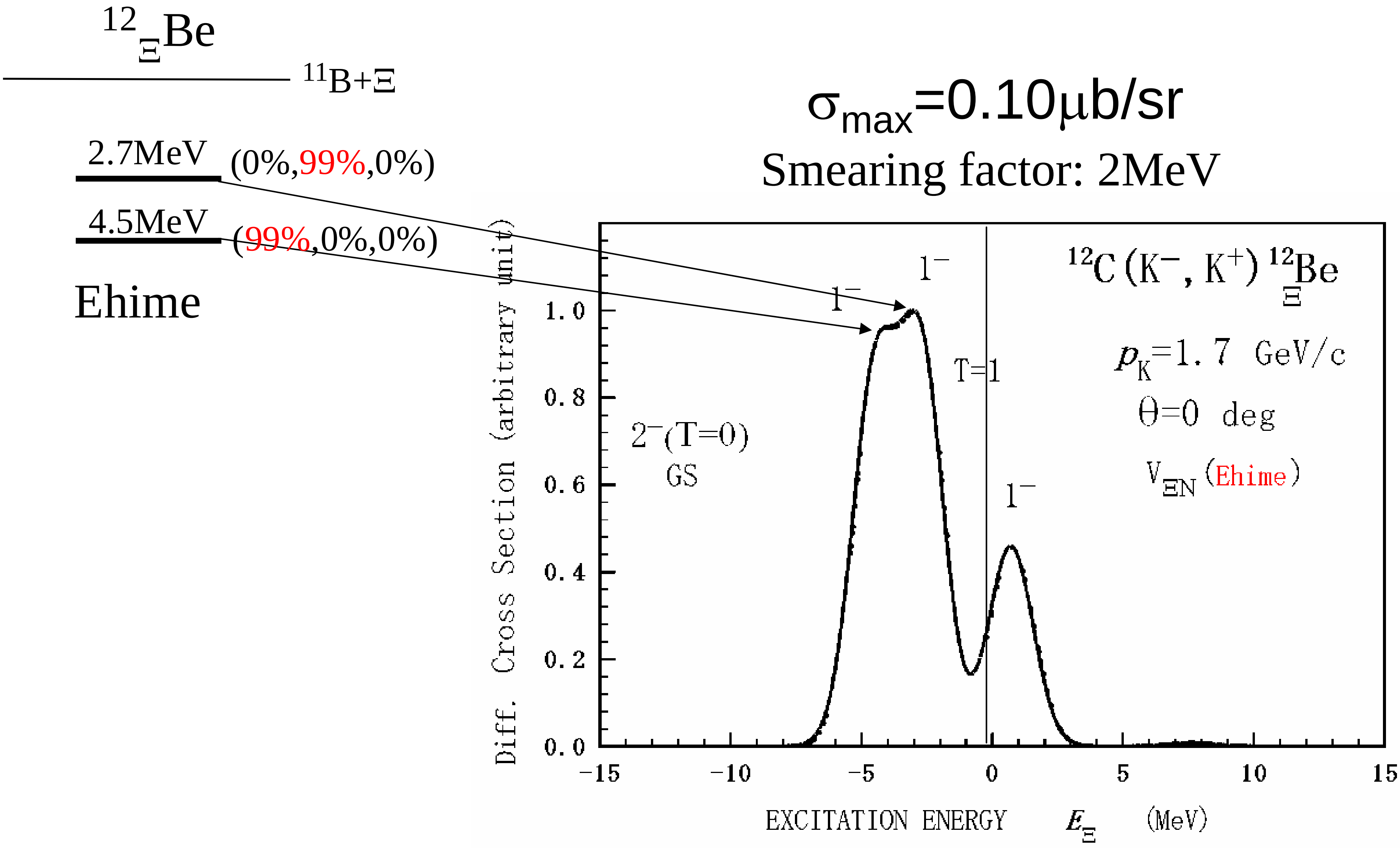
Smearing factor: 2MeV



Excitation Function Ehime

σ_{max}=0.10μb/sr

Smearing factor: 2MeV



Excitation Function ESC04d

$^{12}_{\Xi}$Be

^{11}B+Ξ

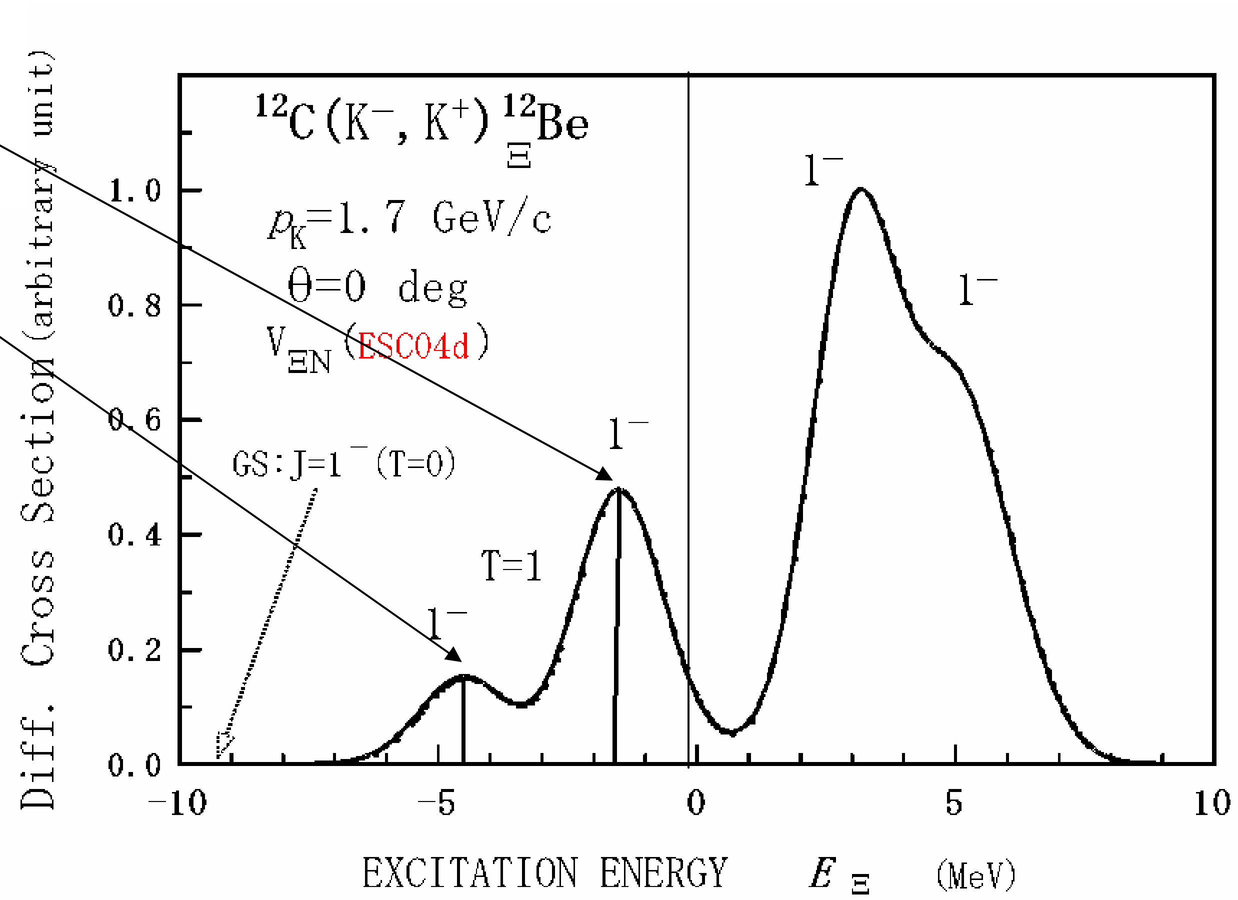
1.5MeV (13%,34%,49%)

4.5MeV (59%,39%,1%)

ESC04d

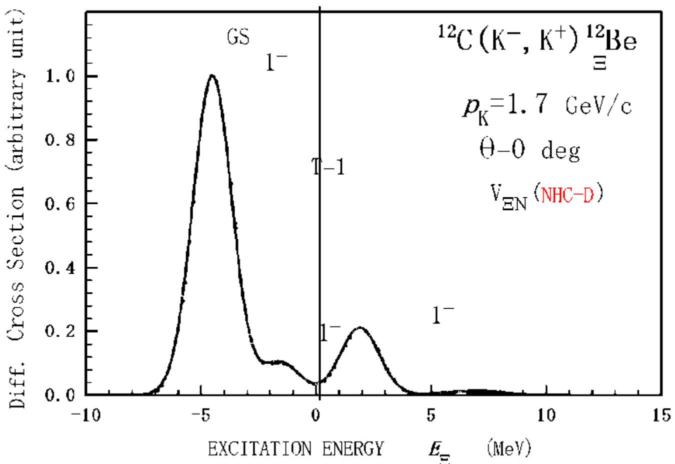
σ_{max}=0.16μb/sr

Smearing factor: 2MeV

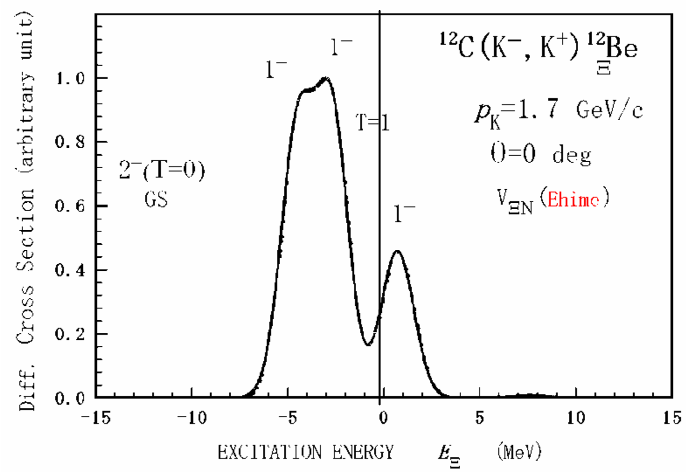


Comparison of excitation functions

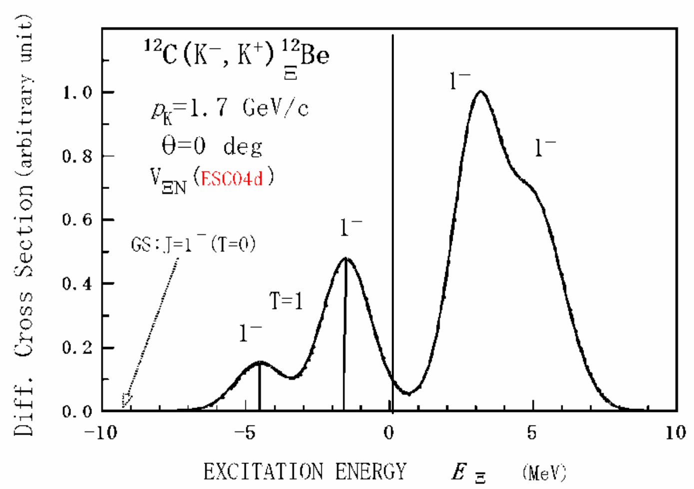
NHC-D



Ehime



ESC04d



- Excitation spectra reflect the character of the N-Ξ interactions

Conversion width ($N\Xi$-$\Lambda\Lambda$)

	1_1^-		1_2^-	
	BE(MeV)	Γ(Mev)	BE(MeV)	Γ(MeV)
NHC-D	4.50	-2.04	1.55	-1.32
Ehime	4.50	-1.19	2.69	-1.13
ESC04d	4.51	-8.83	1.50	-9.09

- Calculated using the imaginary part of the YNG interactions with the shell model wave functions.

Summary

- We performed the shell model calculation for $^{12}_{\Xi}Be$ using the N-Ξ interactions, NHC-D, Ehime and ESC04d.
  - The level schemes and wave functions are different for the different interactions.
- Using the shell model wave functions we calculated the excitation functions of the $^{12}C(K^{-},K^{+})^{12}_{\Xi}Be$ reaction in the DWIA approximation.
  - The excitation functions reflect the character of the N-Ξ interactions
    →Possibility of the exploring the N-Ξ interaction