Spin dependence of ΞN interaction and Ξ hypernuclear production spectrum

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Poster Session T13
Poster Session T19

Introduction

Development of the hypernuclear study opens new era.

Our Interest

1. Ξ hypernuclear state and production spectrum (J-PARC, E05)

   Doorway to S=-2 sector, bound or unboud ?, ΞN interaction

   - What the production spectrum will be ?
   - Is it possible to extract the infromation of ΞN interaction from the observable ?

2. Impurity effect by Λ particle in p-sd shell hypernuclei

   Increasing knowledge for ΛN interaction

   Spectroscopy of sd shell hypernuclei wll be available

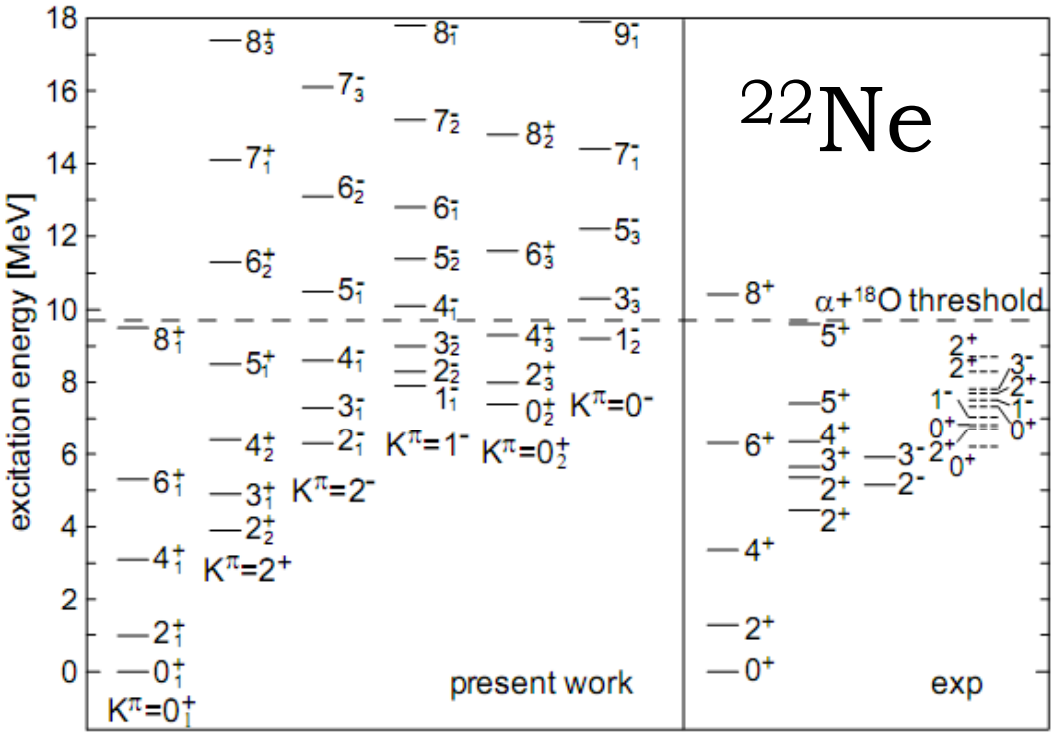
   - Coexistence of the cluster and shell structure in sd shell nuclei
   - How does the Λ particle affect and change the nuclear structure ?

Theoretical model for spectroscopy of p-sd-(pf) shell hypernuclei

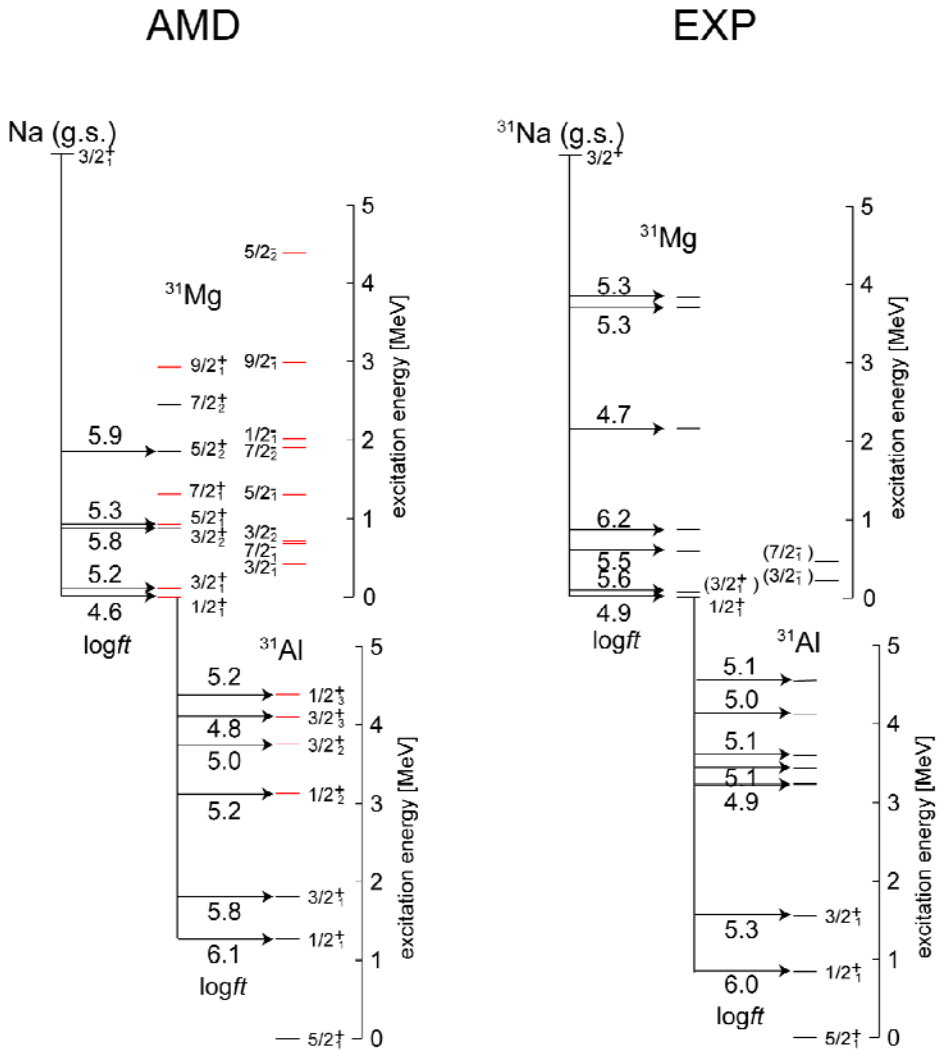
- Shell model
- Cluster model
- Antisymmetrized Molecular Dynamics

Application of AMD to ordinary nuclei

Stable nucleus



Unstable nucleus



Theoretical Framework of ccAMD

An extention of AMD for the system with (multi) strangeness

Trial Wave Function

- Parity projected wave function
- Superposition for each baryon channel under consideration
- Gaussian form of each single particle wave packets

$$|\Psi^{\pm}\rangle = \frac{1 \pm \hat{\mathcal{P}}}{2} |\Psi\rangle, \qquad |\Psi\rangle = \sum_a x_a |\Phi^a\rangle, \qquad |\Phi^a\rangle = \frac{1}{\sqrt{A!}} \det\left[|\varphi_i^a(j)\rangle\right],$$

$$|\varphi_i^a\rangle = |\phi_i^a\rangle \otimes |\sigma_i^a\rangle \otimes |f_i^a\rangle$$

$$\langle \boldsymbol{r}|\phi_i^a\rangle = \left(\frac{2\nu}{\pi}\right)^{3/4} \exp\left[-\nu\left(\boldsymbol{r} - \frac{\boldsymbol{z}_i^a}{\sqrt{\nu}}\right)^2 + \frac{\boldsymbol{z}_i^{a2}}{2}\right]$$

Hamiltonian

- Effective interaction for low-momentum model space
- NN: Volkov, Gogny, …
- YN: G-Matrix interaction ESC04D, NHC-D, Ehime, etc..

$$\hat{H} = \sum_i \hat{t}_i - \hat{T}_{\rm CM} + \frac{1}{2}\sum_{i\neq j} \hat{v}_{ij}^{NN} + \frac{1}{2}\sum_{i\neq j} \hat{v}_{ij}^{YN} + \Delta M,$$

Theoretical Framework of ccAMD

Procedure of the calculation

Variational Calculation

- Optimization of variational parameters
- Imaginary time development method

$$\frac{\mathrm{d}x_a}{\mathrm{d}t} = -(\lambda + i\mu)\frac{1}{\hbar}\frac{\partial \tilde{\mathcal{H}}^{\pm}}{\partial x_a^*}, \qquad \frac{\mathrm{d}u_i^a}{\mathrm{d}t} = -(\lambda + i\mu)\frac{1}{\hbar}\left[\frac{\partial \tilde{\mathcal{H}}^{\pm}}{\partial u_i^{a*}} + \sum_k \eta_k^a \frac{\partial \tilde{\mathcal{W}}_k^a}{\partial u_i^{a*}}\right],$$

Angular Momentum Projection

$$\left|\Phi_K^s; J^{\pm} M\right\rangle = \frac{8\pi^2}{2J+1}\int \mathrm{d}\Omega\, \mathcal{D}^{J}_{MK}{}^{*}(\Omega)\, \hat{R}(\Omega)\, \frac{1 \pm \hat{\mathcal{P}}}{2}\left|\Phi^s\right\rangle,$$

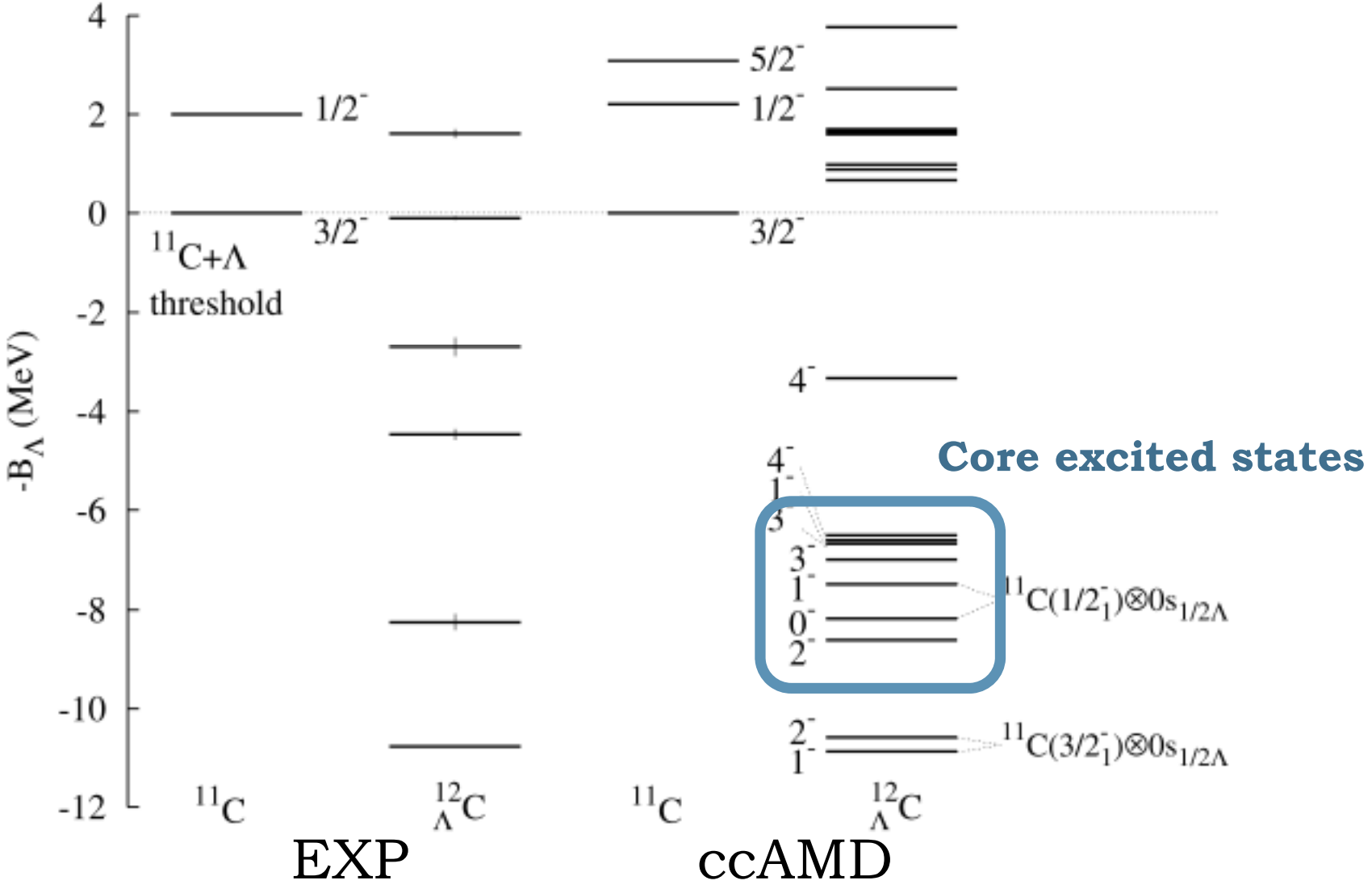
Generator Coordinate Method (GCM)

- Superposition of the w.f. with different configurations
- Diagonalization of Hamiltonian

$$\begin{Bmatrix} \mathcal{N}^{J^{\pm}}_{sK,s'K'} \\ \mathcal{H}^{J^{\pm}}_{sK,s'K'} \end{Bmatrix} = \left\langle \Phi_K^s; J^{\pm} M \middle| \begin{Bmatrix} 1 \\ \hat{H} \end{Bmatrix} \middle| \Phi_{K'}^{s'}; J^{\pm} M \right\rangle. \qquad \left|\Psi^{J^{\pm} M}_{\text{Hyp.}}\right\rangle = \sum_{sK} g_{sK} \left|\Phi_K^s; J^{\pm} M\right\rangle.$$

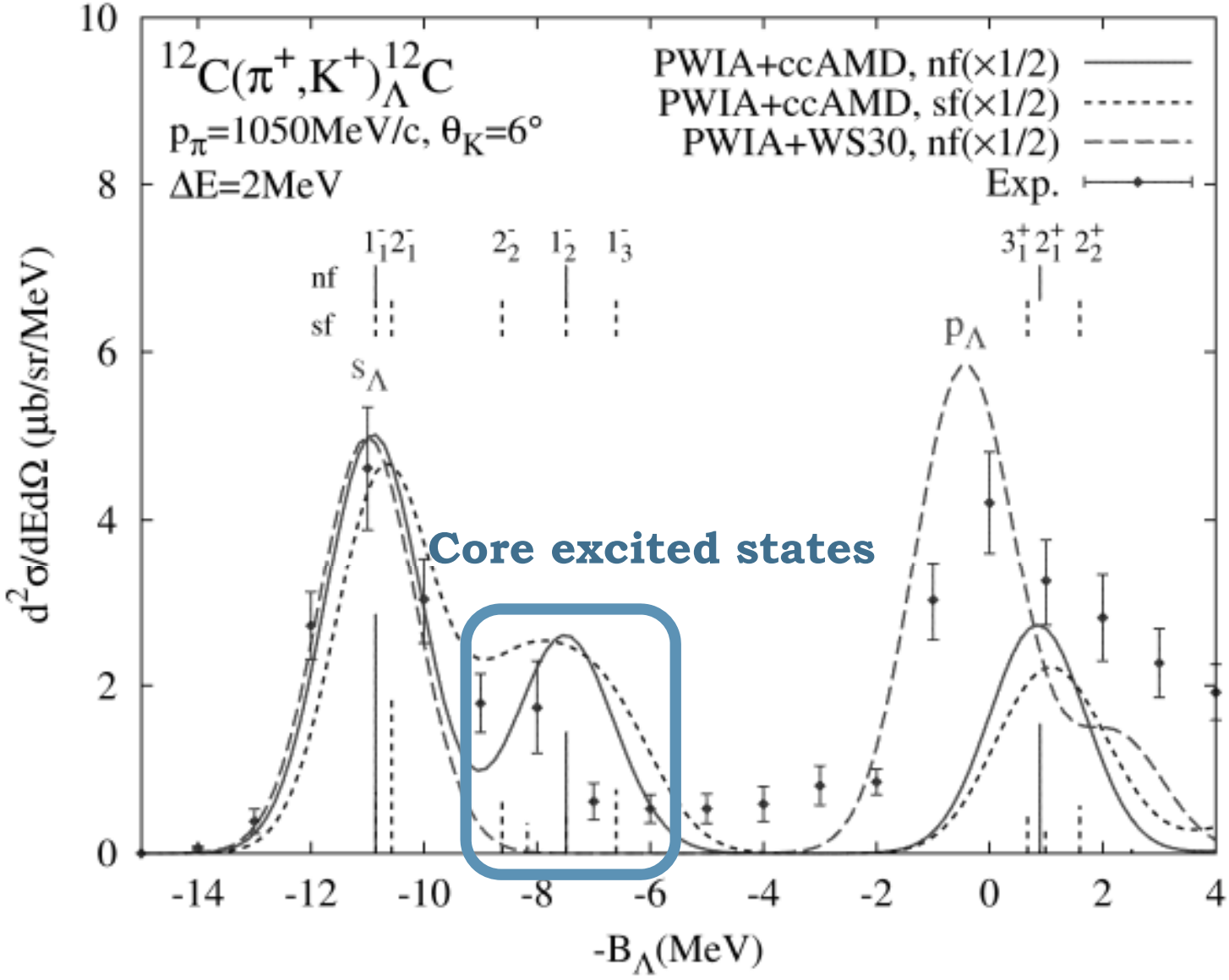
$^{12}_{\Lambda}$C: Level Scheme

- ^{11}C(g.s.) x $s_{1/2}$ dominates ground state doublet
- Many core excited states appear (further detailed study is needed)



$^{12}_{\Lambda}$C: (π^+,K^+) spectrum

- Peak from the core excited states appears between s_Λ and p_Λ



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

Level scheme, Production spectrum and their dependence on YN int.

H. Matsumiya (T13, Today)

Introduction

Motivation

Ξ hypernuclear state and production spectrum (J-PARC, E05)

Doorway to S=-2 sector, bound or unboud ?, ΞN interaction

- What the production spectrum will be ?
- Is it possible to extract the ΞN interaction from the observable ?

Method

- Coupled channel AMD calculation
  (^{11}B x Ξ- and ^{11}Be x Ξ^0 channels)
- ΞN interaction: G-Matrix Int. derived from
  Ehime, NHC-D and ESC04d

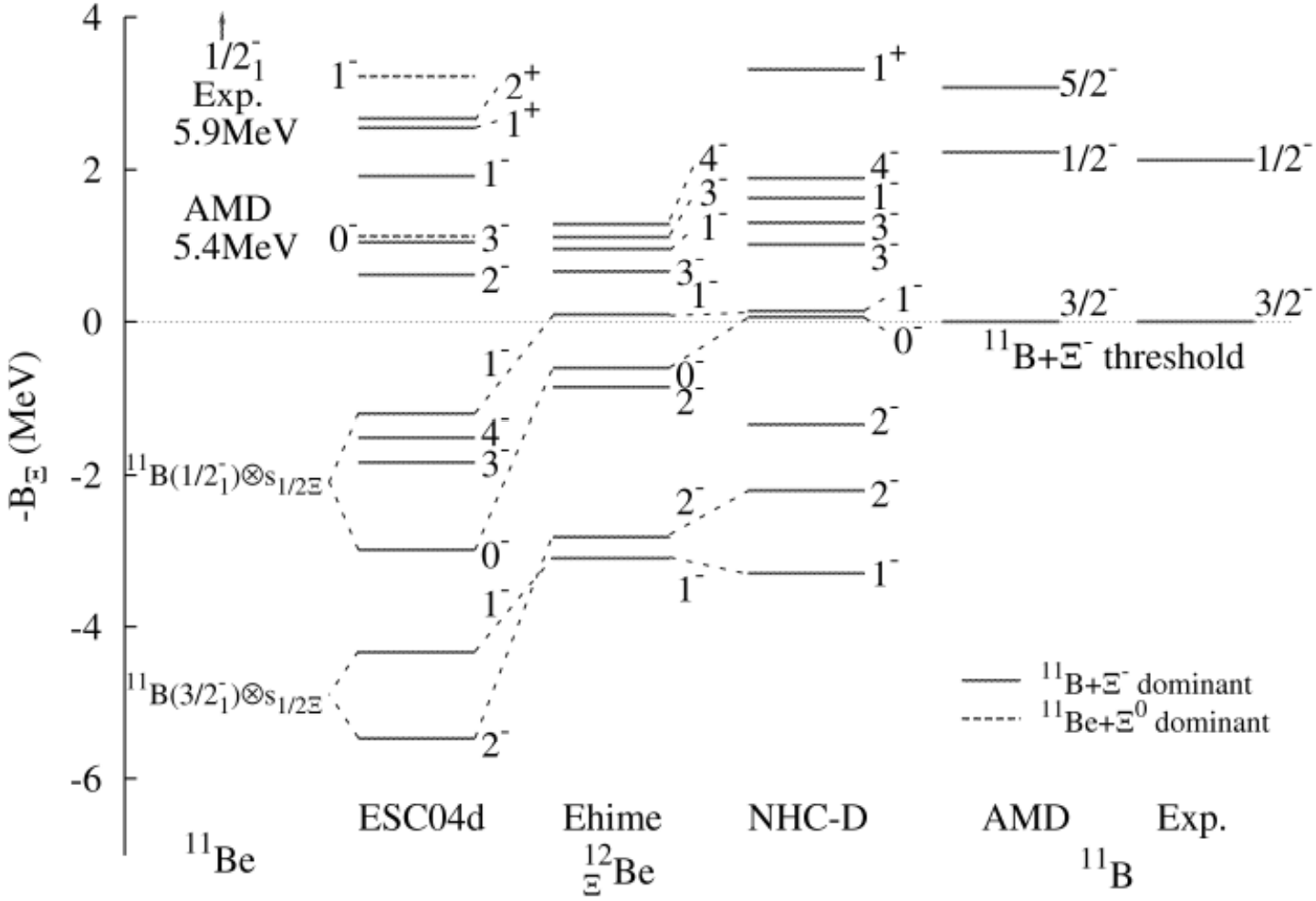
  ESC04d: Th. A. Rijken and Y. Yamamoto, arXiv:nucl-th/0608074.
  Ehime: Y. Yamaguchi *et al.*, PTP 105 (2001), 627.
  G-matrix: Y. Yamamoto, private communication

- PWIA approx for production spectrum

  T. Harada and S. Hirenzaki, (KEK summer school 2006)

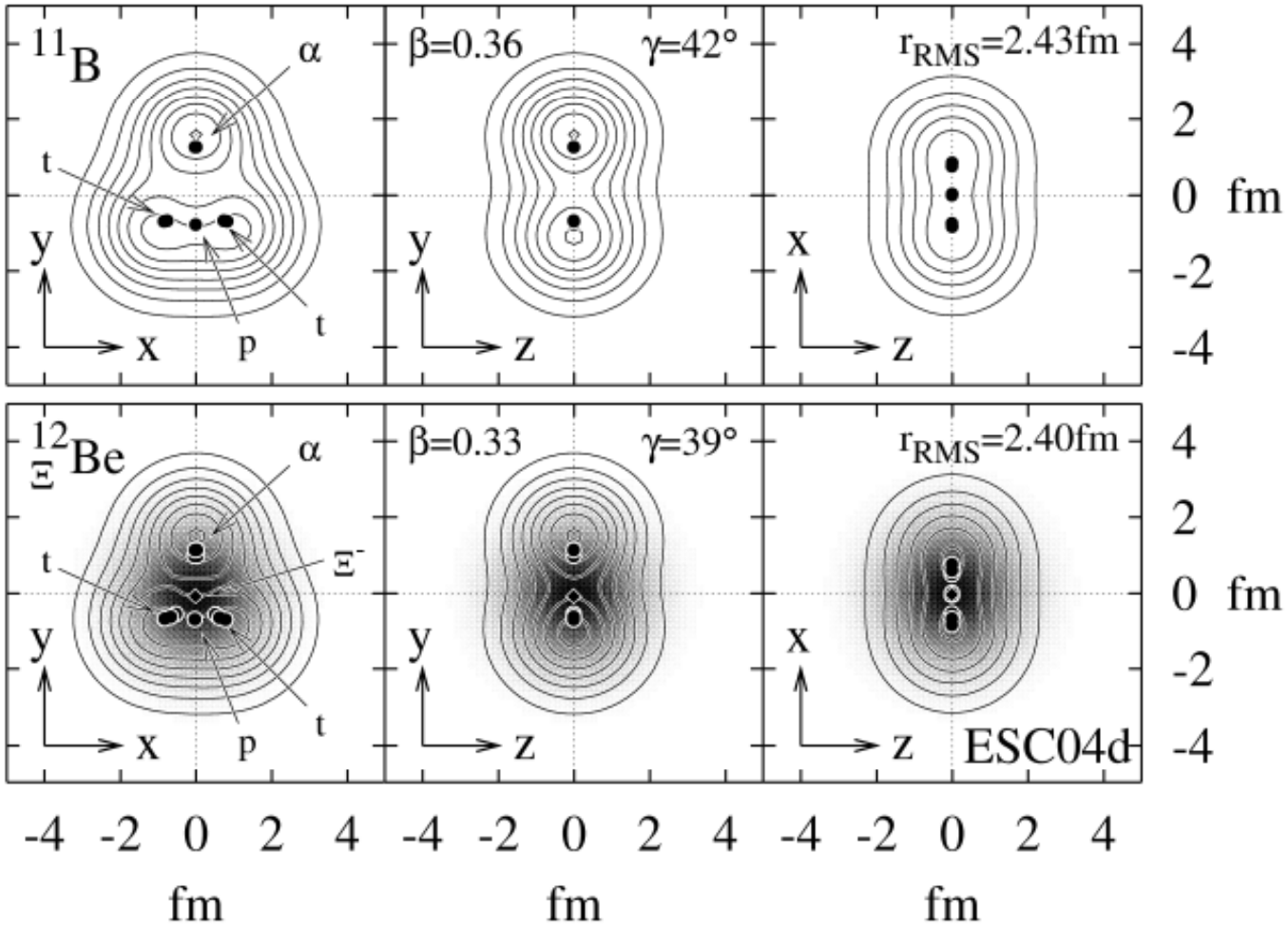
$^{12}_{\Xi}$Be: Level Scheme

- The order of the ground state doublet depends on the effective int.
  - ESC04d (Strong attraction for spin triplet)
  - NHC-D(repulsion for spin-triplet)
- Small mixing between Ξ^- and Ξ^0 channels
- An almost pure configuration (^{11}B(g.s.)xΞ^- in the g.s. doublet



Density distribution of the g.s.

- ^{7}Li + α cluster-like structure of ^{11}B
- $0s_{1/2}$ nature of the Ξ single particle wave function
- Small reduction of the inter-cluster distance in $^{12}_{\Xi}$Be



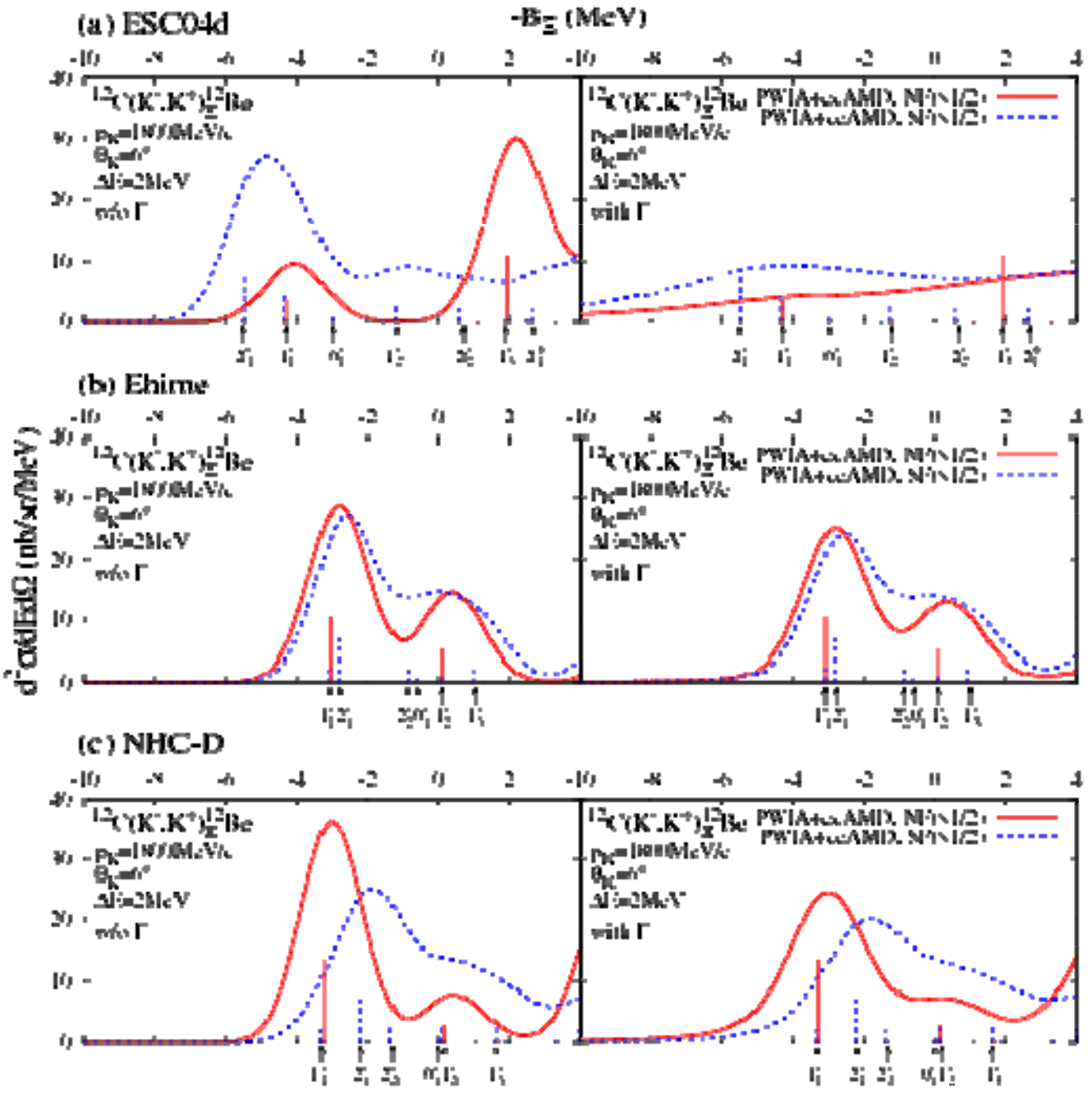
$^{12}C(K^-,K^+)^{12}_{\Xi}Be$ spectrum

Spin non flip

Spin flip

- Very large conversion width of ESC04d

- Peak position and height of spin flip, non flip cross section are sensitive to spin-spin interaction



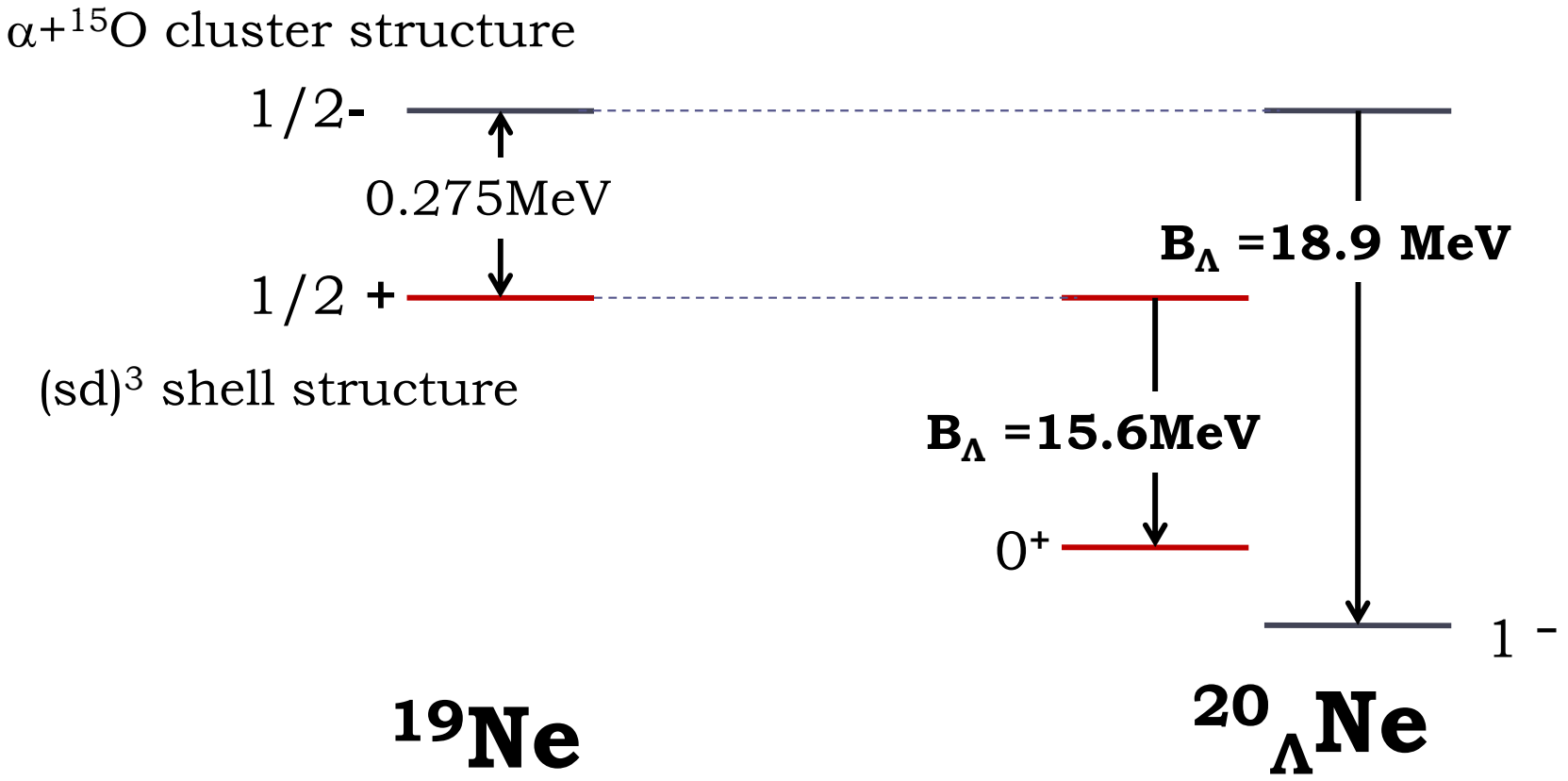
Impurity effect of Λ particle in sd-shell nuclei

M. Isaka (T19, Today)

Predicted parity inversion in $^{20}_{\Lambda}$Ne

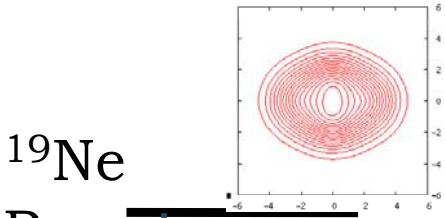
T. Sakuda and H. Bandō, Prog. Theor. Phys. **78** (1987), 1317.

- Two different kinds of structure coexist in ^{19}Ne
- Cluster state becomes the ground state of $^{20}_{\Lambda}$Ne, due to the large shrinkage effect ➡ parity inversion



Results and Discussion ($^{20}_{\Lambda}$Ne)

- Binding energy of Λ in its s orbital

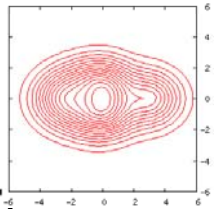


^{19}Ne Pos.

β = 0.273
r_{RMS}=2.81fm

B_Λ = 16.72 (MeV)
Δr = 0.01fm

Pos.⊗ Λ (s)



^{19}Ne Neg.

β = 0.450
r_{RMS}=2.91fm

B_Λ = 16.06(MeV)
Δr = 0.04fm

Neg. ⊗ Λ (s)

$1/2^+$ shell state

^{19}N

B_Λ = 15.6MeV
Δr = 0.3 fm

Pos.⊗ Λ (s)

0^+

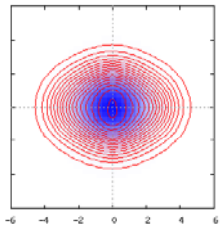
$1/2^-$ cluster state

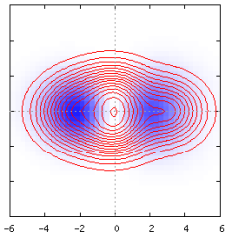
B_Λ =18.9 MeV
Δr = 0.3 fm

Neg. ⊗ Λ (s)

1^-

$^{20}_{\Lambda}$Ne





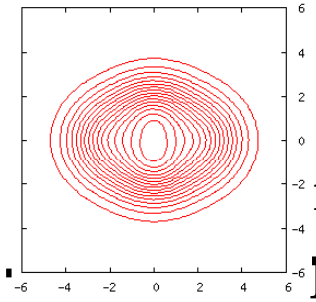
AMD with YNG[1]

Calc. (Sakuda et al.) [2]

[1] Y. Yamamoto, et. Al.,, Prog. Theor. Phys. Suppl. **117** (1994), 361.
[2] T. Sakuda and H. Bandō, Prog. Theor. Phys. **78** (1987), 1317.

Results and Discussion ($^{20}_{\Lambda}$Ne)

- Binding energy of Λ in its p orbital



^{19}Ne

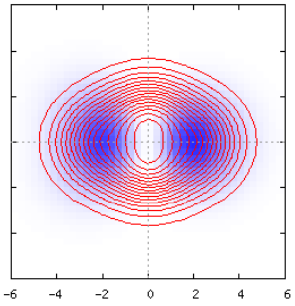
Pos.

$\beta = 0.273$

$r_{RMS}=2.81$fm

B_Λ=5.74 (MeV)

Pos.⊗ Λ (p)



^{19}Ne

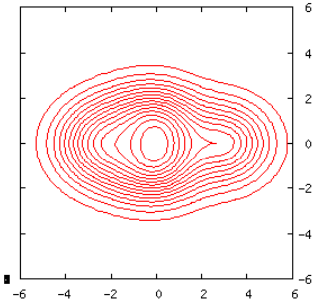
Neg.

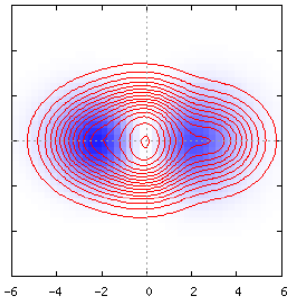
$\beta = 0.450$

$r_{RMS}=2.91$fm

B_Λ=6.25(MeV)

Neg. ⊗ Λ (p)





AMD with YNG[1]

[1] Y. Yamamoto, T. Motoba, H. Himeno, K. Ikeda and S. Nagata, Prog. Theor. Phys. Suppl. **117** (1994), 361.

Summary

1. We have extended Antisymmetrized Molecular Dynamics to the multi strangeness system.

2. Application to ${}^{12}_{\Xi}$Be
   - The order of the ground state doublet strongly depends on the spin-spin interaction of ΞN interaction
   - Large conversion width in ESC04d interaction
   - Production spectrum (Peak position and hight) strongly depends on the ΞN interaction

     ➡ possibility to determine the sign of spin-spin int.
3. Application to ${}^{20}_{\Lambda}$Ne
   - Parity inversion does not occur.

     Contradicting result to the cluster model calculation.

     Shrinkage effect is not so large.
   - Λ particle in p-shell causes the parity inversion in the excited state of ${}^{20}_{\Lambda}$Ne