

非弾性散乱を利用した不安定核 核構造研究

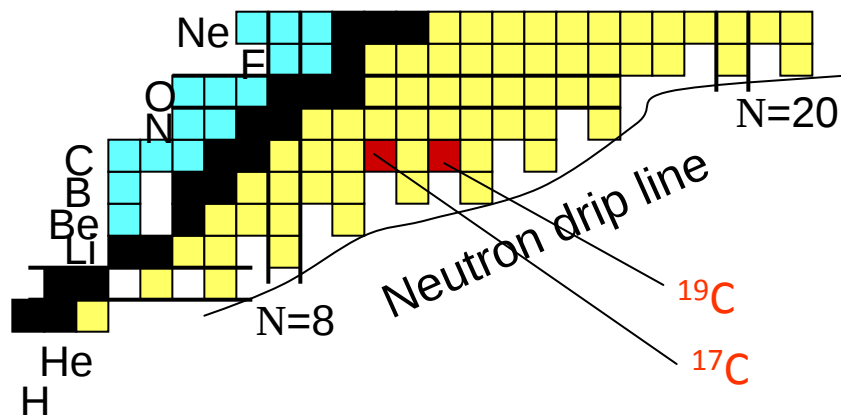
佐藤義輝 東京工業大学

Unbound excited states in $^{19,17}\text{C}$

— Ground state deformation property of carbon isotopes—

Y.Satou et al.,

Phys. Lett. B 660, 320(2008).



- T.Nakamura et al., PRL83,1112(1999).
- V.Maddalena et al., PRC63,024613(2001).
- N.Fukuda et al., PRC70,054606(2004).
- R.Kanungo et al., NPA757,315(2005).
- Z.Elekes et al., PLB614,174(2005).
- T. Nakamura et al., PRL96, 252502(2006).
- T. Sugimoto et al., PLB654,160(2007).
- Y.Kondo et al., PRC79, 014602(2009).

Physics Background

- **Disappearance of magicity at N=20**
T.Motobayashi et al., PLB346(1995)9.

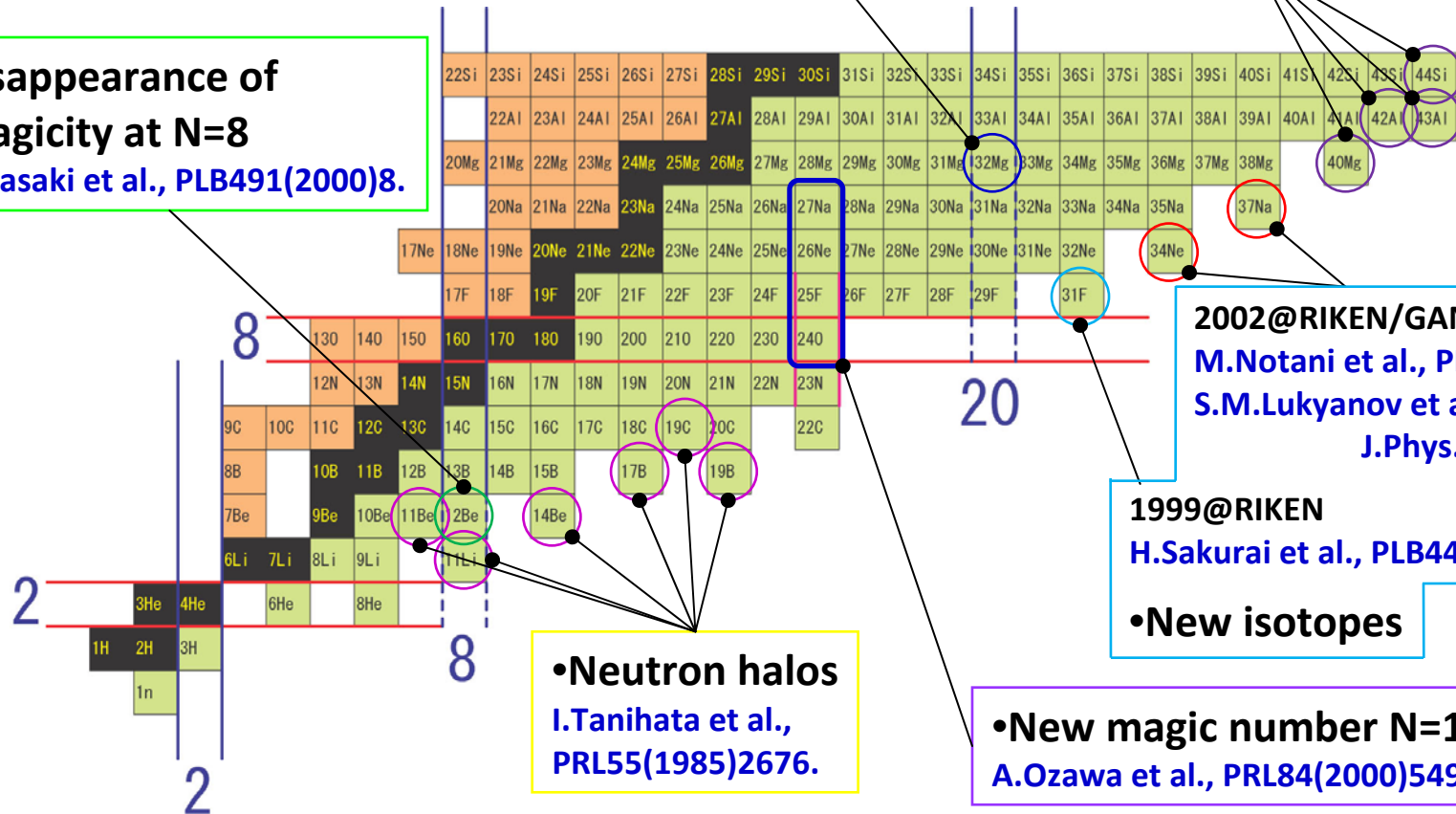
2007@MUS

O.Tarasov et al., PRC75(2007)064613.

T.Baumann et al., Nature 449(2007)1022.

- **Disappearance of magicity at N=8**
H.Iwasaki et al., PLB491(2000)8.

Proton number ↑



2002@RIKEN/GANIL

M.Notani et al., PLB542(2002)49.

S.M.Lukyanov et al.,
J.Phys.G28(2002)L41.

1999@RIKEN

H.Sakurai et al., PLB448(1999)180.

• **New isotopes**

- **Neutron halos**
I.Tanihata et al.,
PRL55(1985)2676.

- **New magic number N=16**
A.Ozawa et al., PRL84(2000)5493.

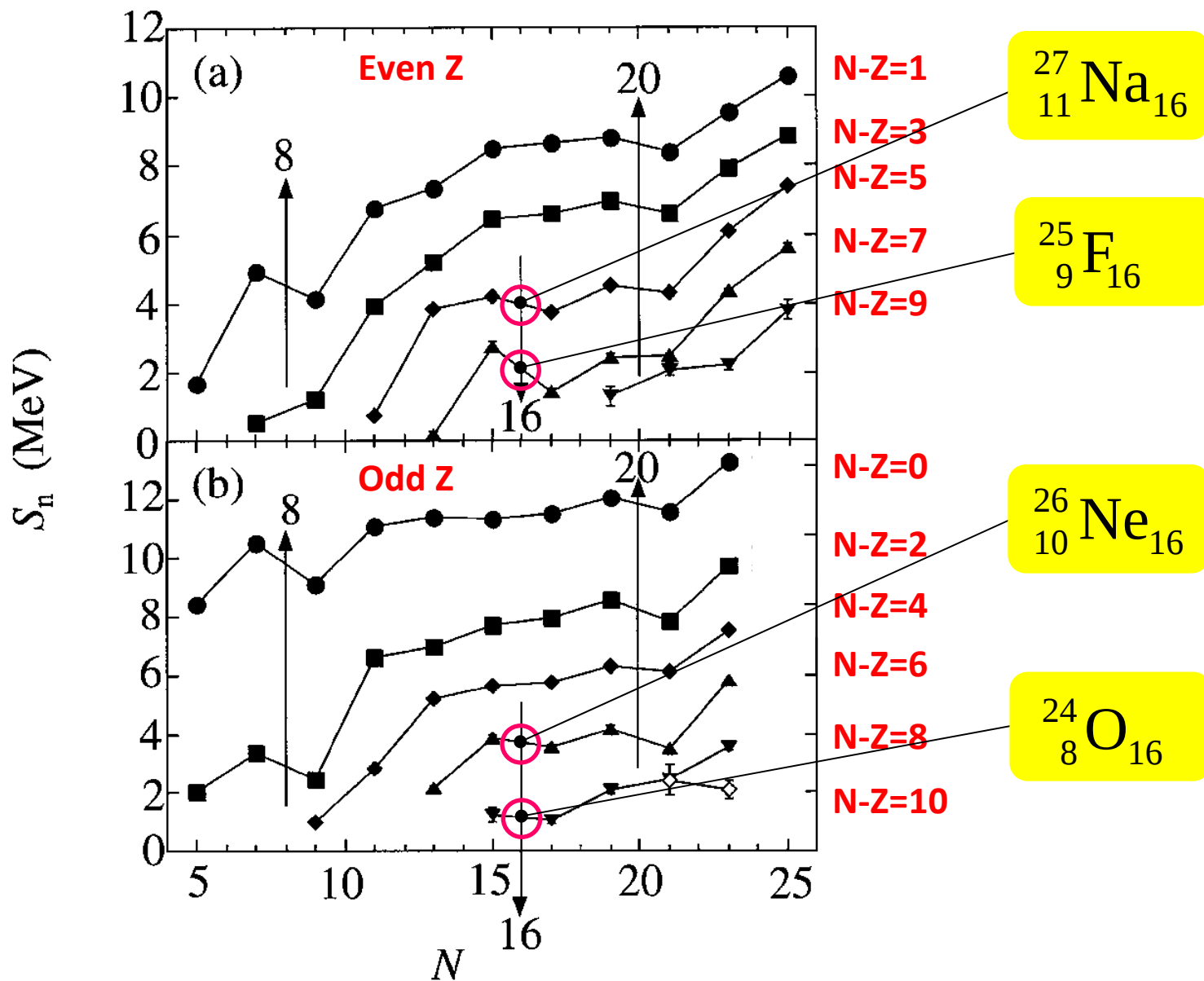
Neutron number →

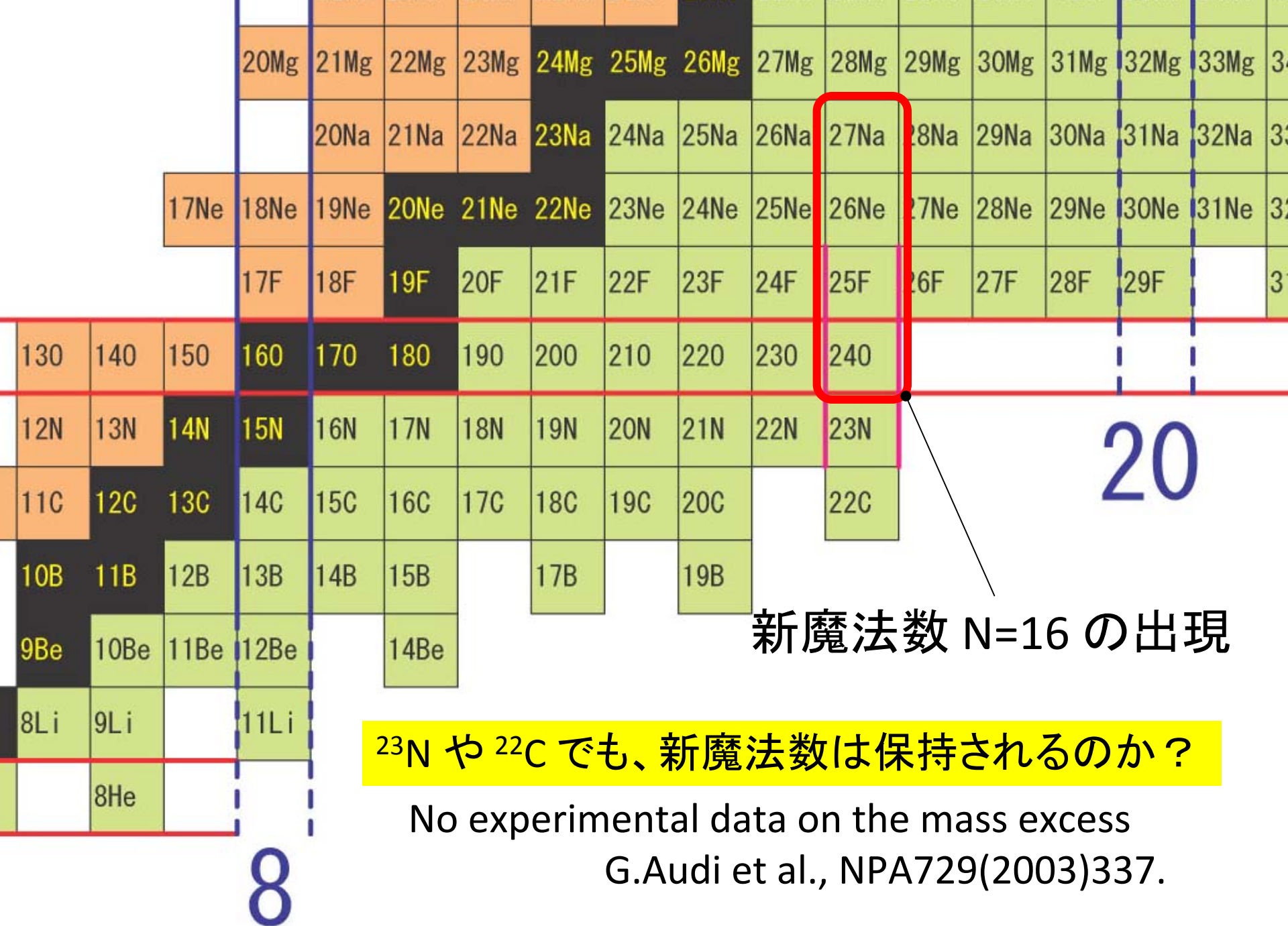
Challenges to nuclear physics

- To establish the drip line
- To accumulate spectroscopic information and find new phenomena

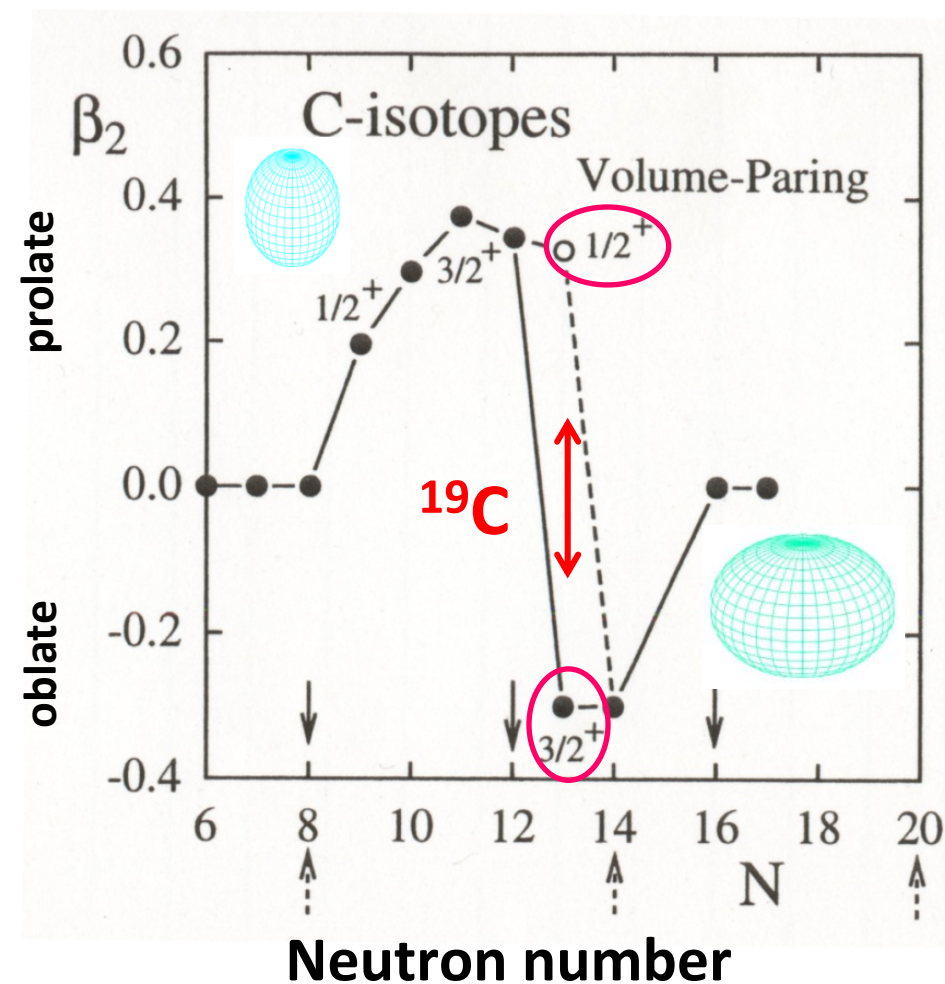
新魔法数 N=16 の出現

A.Ozawa et al.,
PRL84(2000)5493.





炭素同位体の基底状態変形の中性子数依存性



New magic number at $N=16$ in C chain ?

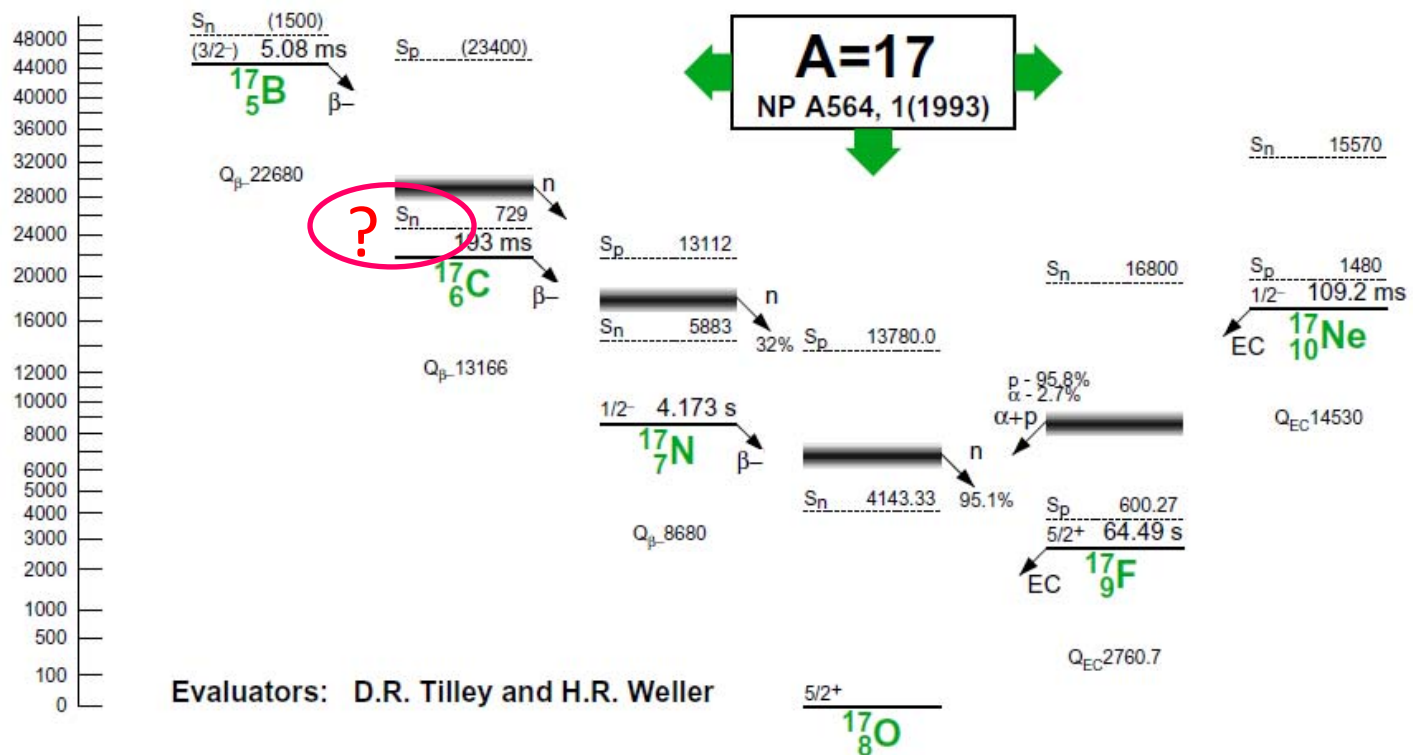
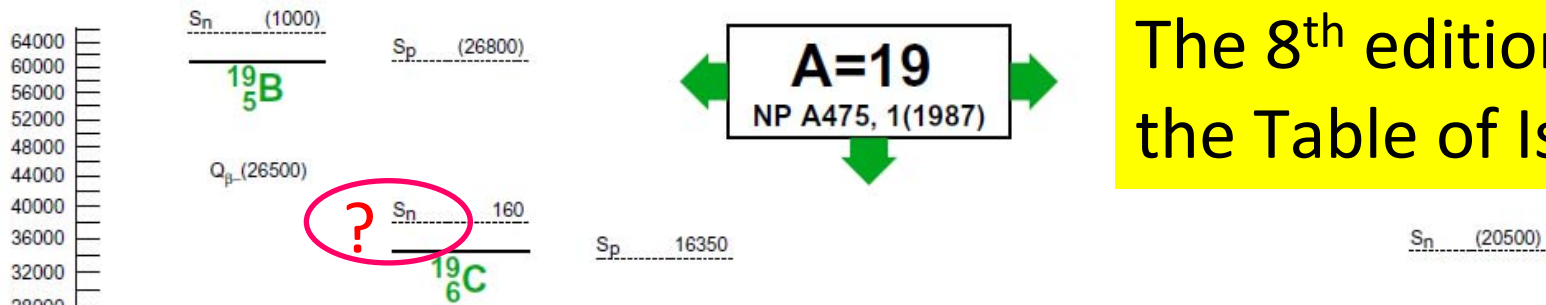
- For ^{19}C with $N=13$, two almost degenerate deformation minima are predicted.
- Definite information on the structure of ^{19}C is important to clarify the possible new shell effect ($N=16$ closure) in the neutron-rich carbon isotopes.

$^{19,17}\text{C}$ 核の基底状態のスピン・パリティ

^{19}C		
Reference	Method	$J^\pi(\text{gnd.})$
D.Bazin et al., PRL74(1995)3569.	$^{19}\text{C} \rightarrow ^{18}\text{C}$	$1/2^+$
D.Bazin et al., PRC57(1998)2156.	$^{19}\text{C} \rightarrow ^{18}\text{C}$	$5/2^+$
T.Baumann et al., PLB439(1998)256.	$^{19}\text{C} \rightarrow ^{18}\text{C}$	$5/2^+$
T.Nakamura et al., PRL83(1999)1112.	$^{19}\text{C} \rightarrow ^{18}\text{C} + \text{n}$ Coulomb	$1/2^+$
V.Maddalena et al., PRC63(2001)024613.	$^{19}\text{C} \rightarrow ^{18}\text{C} + \gamma$	$1/2^+$
R.Kanumgo et al., NPA757(2005)315.	$^{19}\text{C} \rightarrow ^{19}\text{C} + \gamma$	$3/2^+, 5/2^+$
This experiment	$^{19}\text{C} \rightarrow ^{18}\text{C} + \text{n}$ (p,p')	?

^{17}C		
Reference	Method	$J^\pi(\text{gnd.})$
E.Sauvan et al., PLB491(2000)1.	$^{17}\text{C} \rightarrow ^{16}\text{C}$	$3/2^+$
V.Maddalena et al., PRC63(2001)024613.	$^{17}\text{C} \rightarrow ^{16}\text{C} + \gamma$	$3/2^+$
H.Ogawa et al., EPJA13(2002)81.	g-factor	$3/2^+$
E.Sauvan et al., PRC69(2004)044603.	$^{17}\text{C} \rightarrow ^{16}\text{C}$	$3/2^+$
This experiment	$^{17}\text{C} \rightarrow ^{16}\text{C} + \text{n}$ (p,p') reaction	?

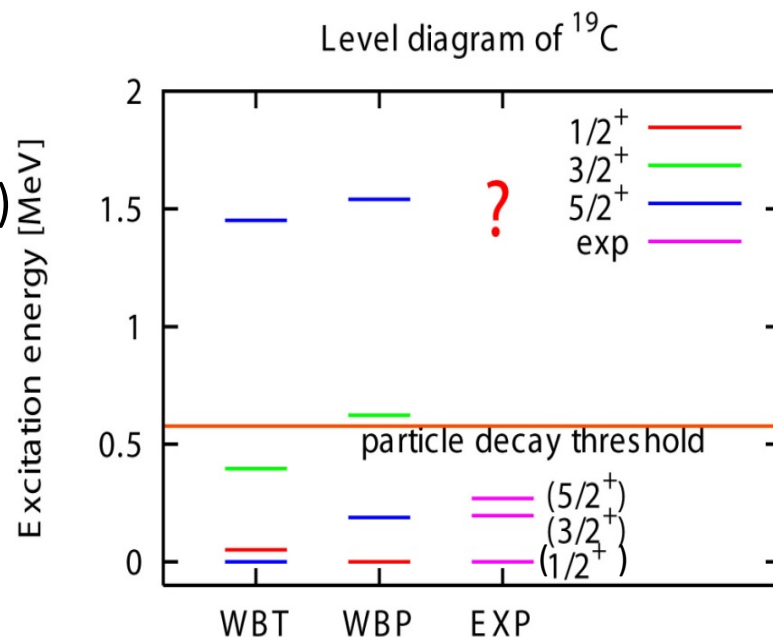
The 8th edition of the Table of Isotopes



実験目的

- ^{19}C 核の基底状態の J^π の決定

- 粒子崩壊閾値より上の準位を探索する
- エクスクルーシブ測定を行う
- (p,p') 反応を利用する
- 手法の較正目的の為、 ^{17}C 核($J^\pi=3/2^+$)も同様の測定を実施



Why use the (p,p') reaction ?

- Theoretical methods, such as Distorted Wave Born Approximation (DWBA), provide a first interpretation of data.

$$\frac{d\sigma}{d\Omega} = \frac{m_a m_b}{(2\pi\hbar^2)^2} \frac{k_b}{k_a} |T_{ba}^{\text{DWBA}}|^2$$

Effective interaction

$$T_{ba}^{\text{DWBA}} = \langle X^{(-)} \chi_b \Phi_{A^*} | V_{ba} | X^{(+)} \chi_a \Phi_A \rangle$$

Nuclear wave functions

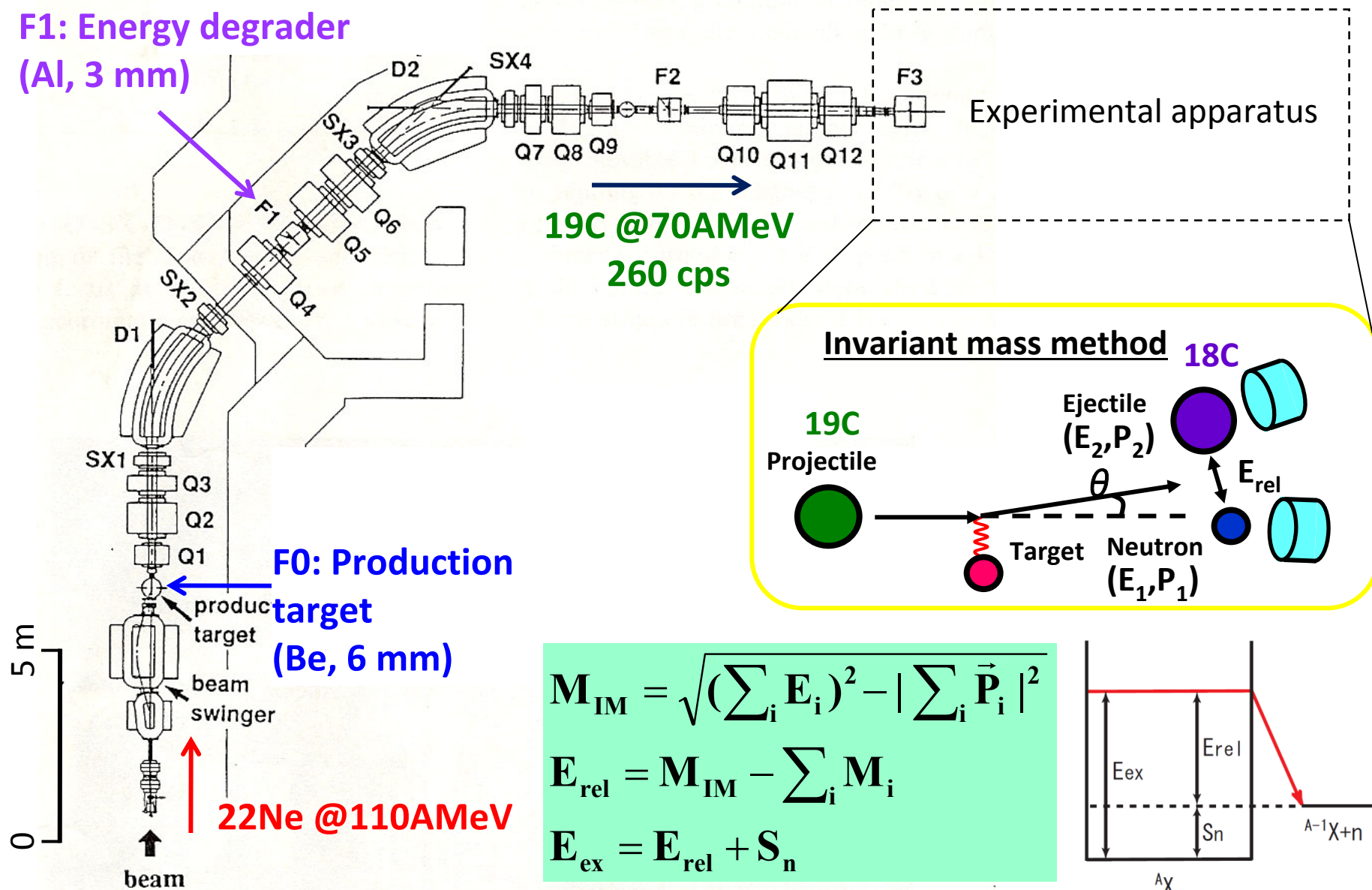
Nucleon spinors

Distorted waves

- The liquid hydrogen target can be used to maximize the number of scattering center per unit energy loss.

RIPS: RIken Projectile fragment Separator

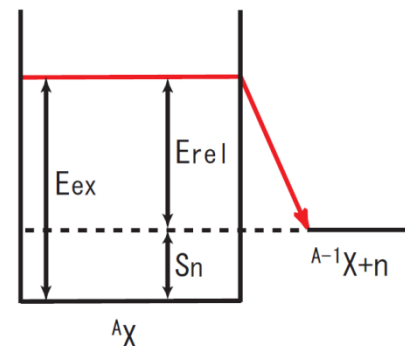
F1: Energy degrader
(Al, 3 mm)



$$M_{IM} = \sqrt{(\sum_i E_i)^2 - |\sum_i \vec{P}_i|^2}$$

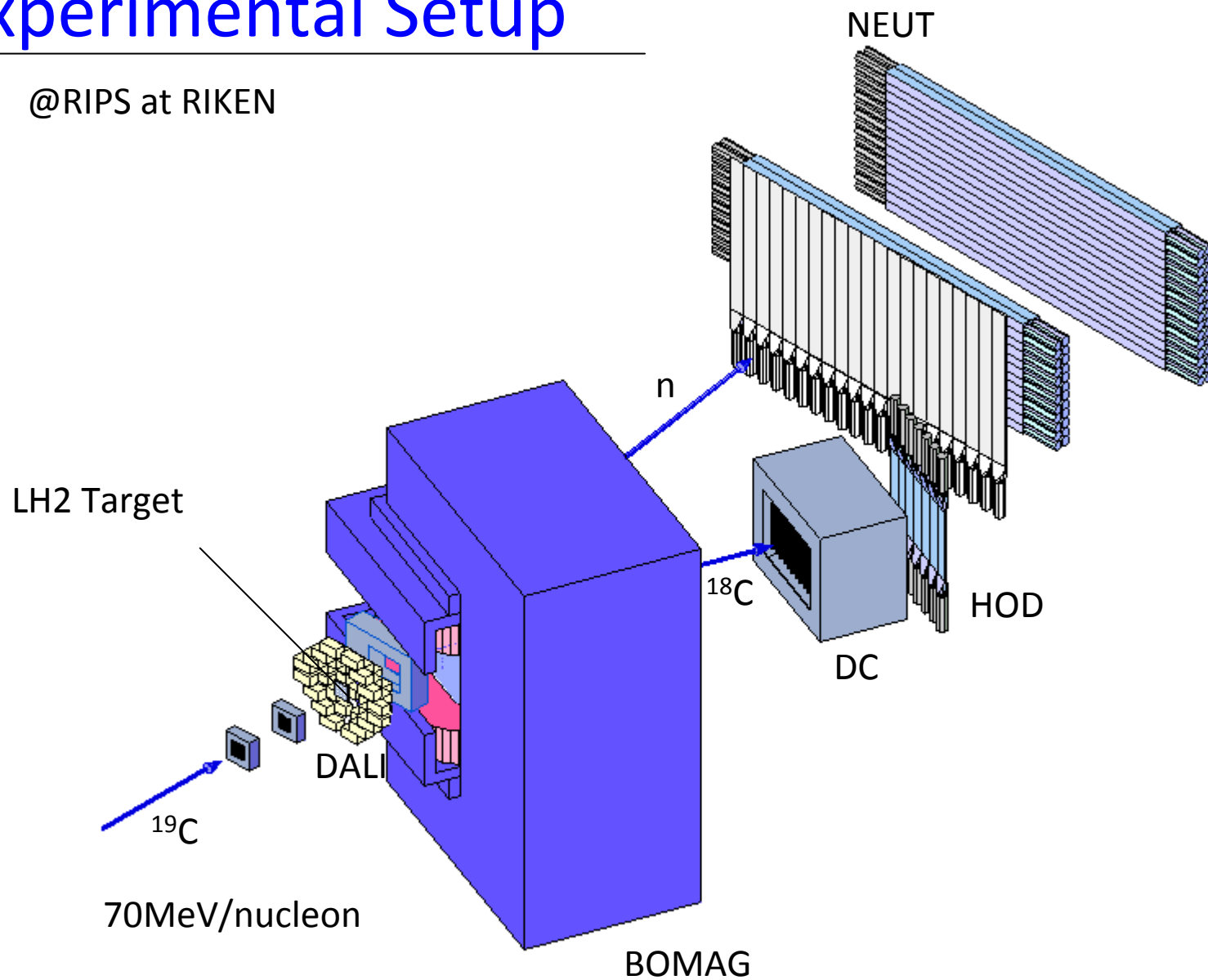
$$E_{rel} = M_{IM} - \sum_i M_i$$

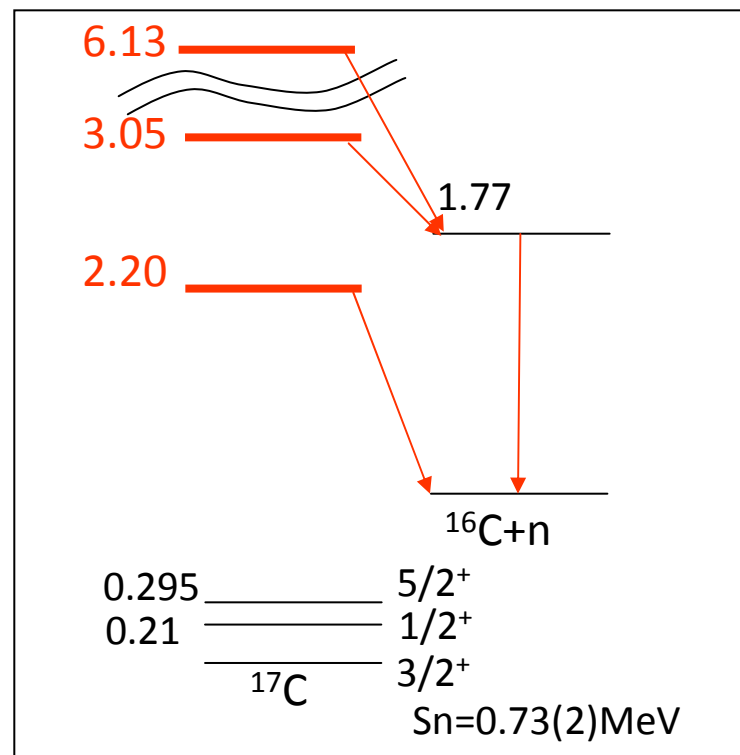
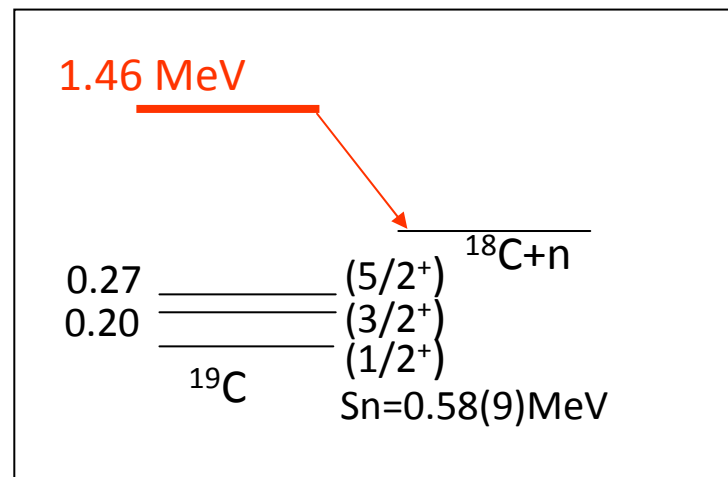
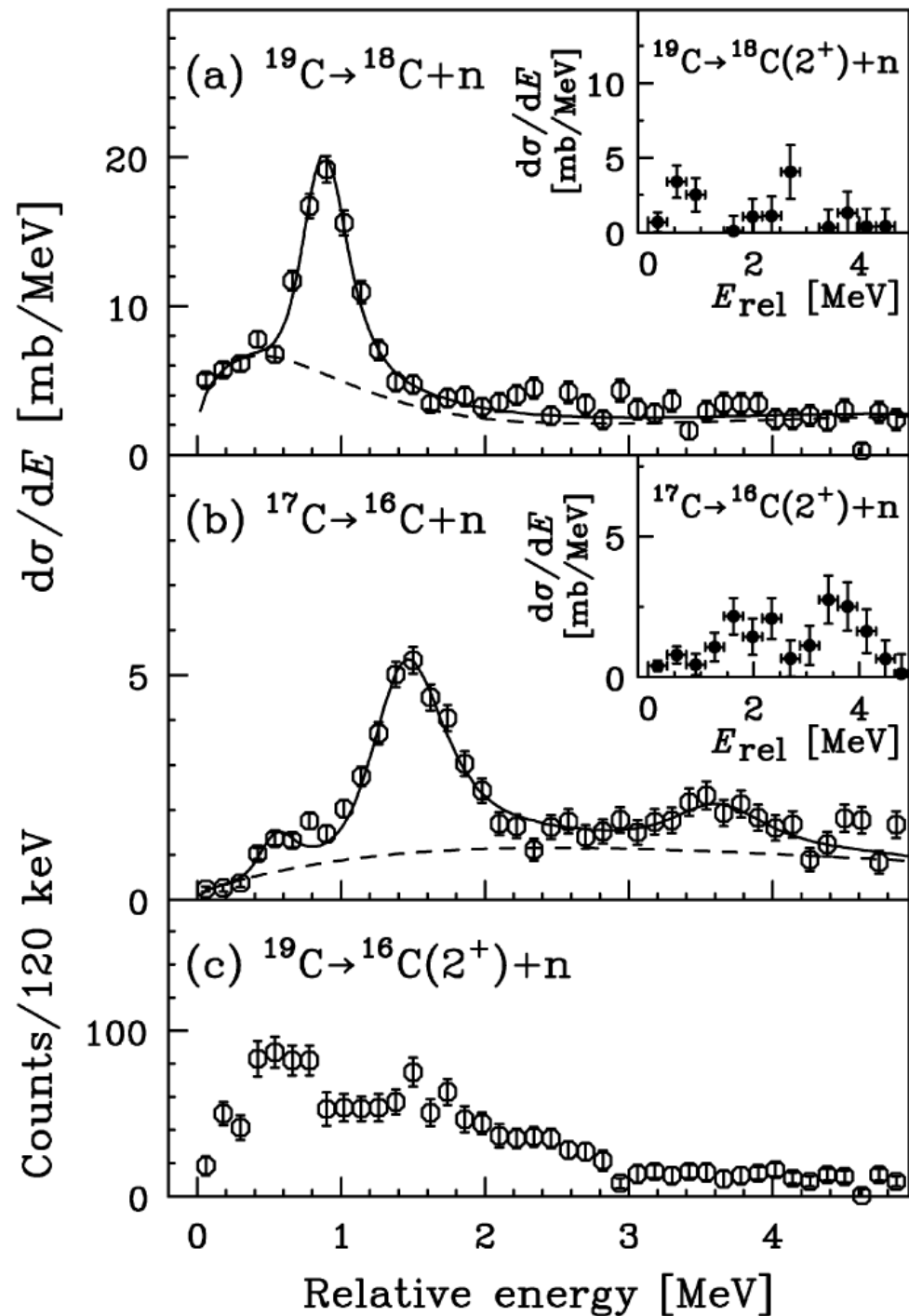
$$E_{ex} = E_{rel} + S_n$$



Experimental Setup

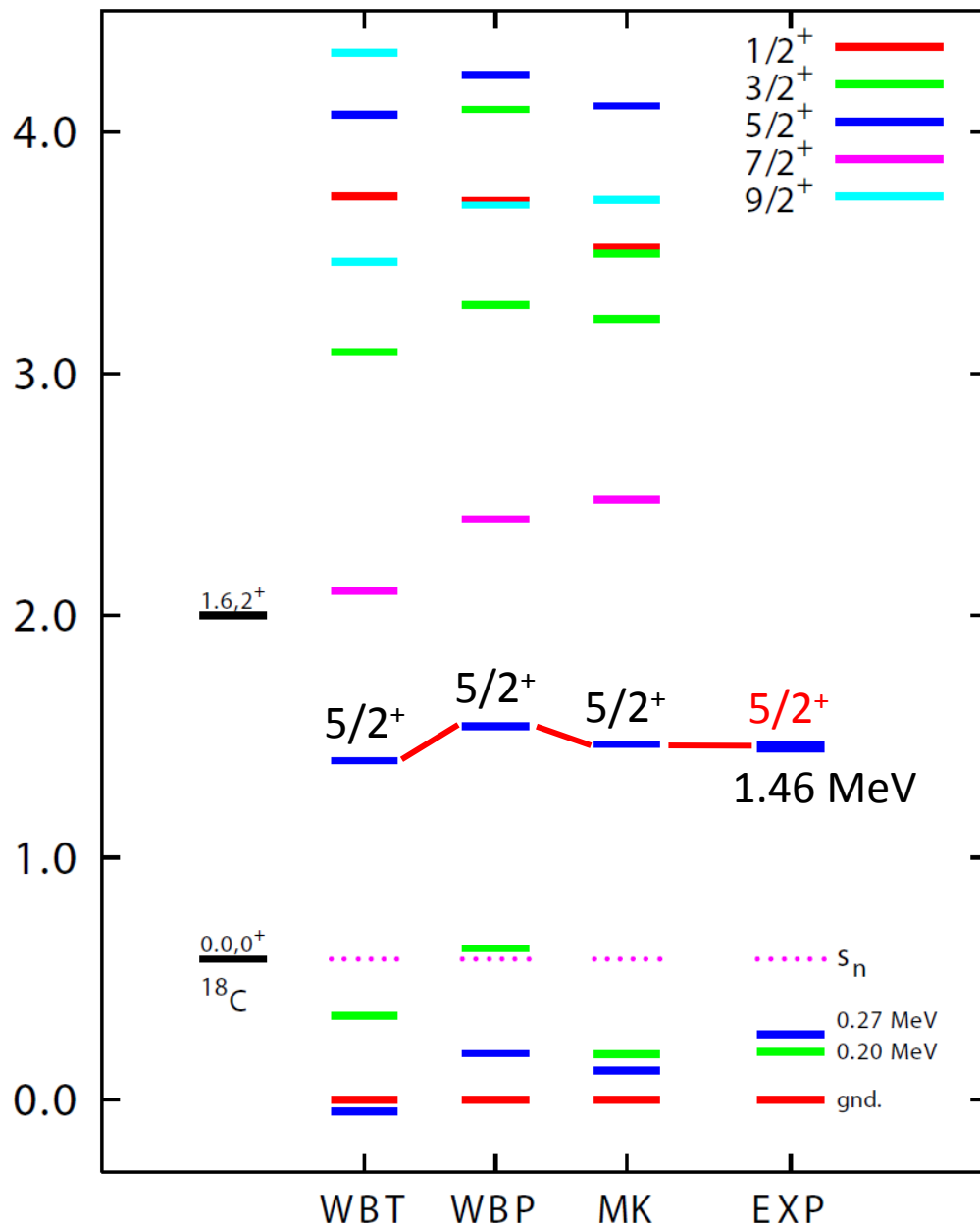
@RIPS at RIKEN





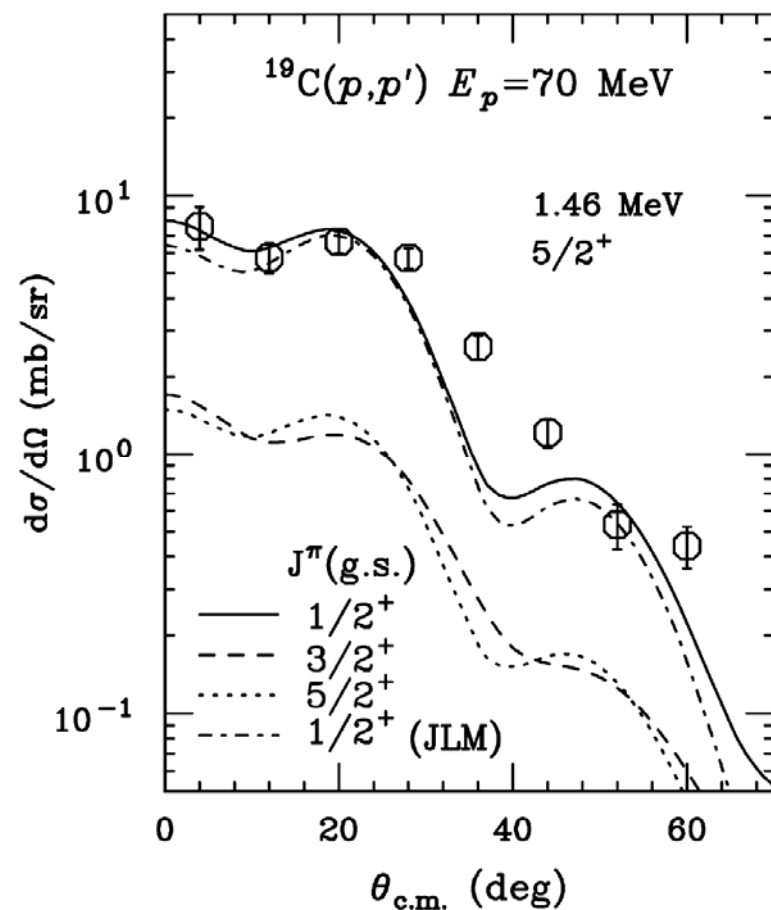
Energy level diagram of ^{19}C

Excitation energy [MeV]

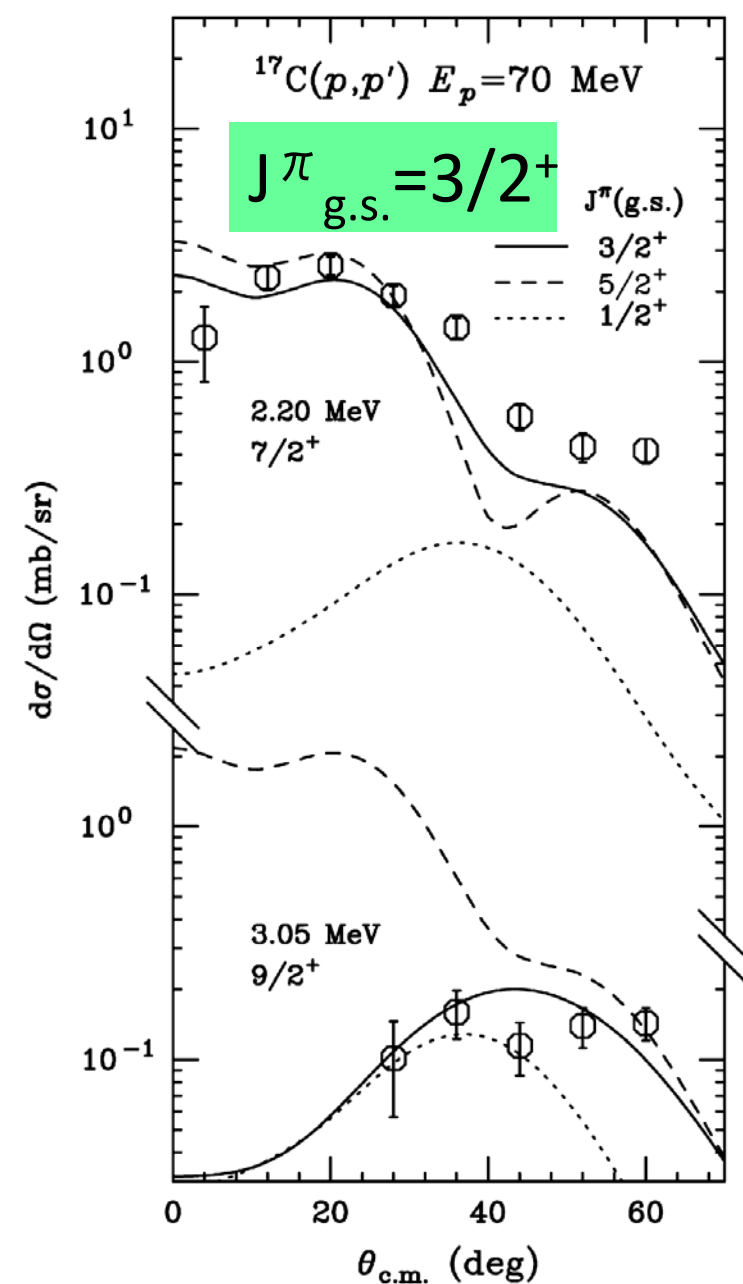
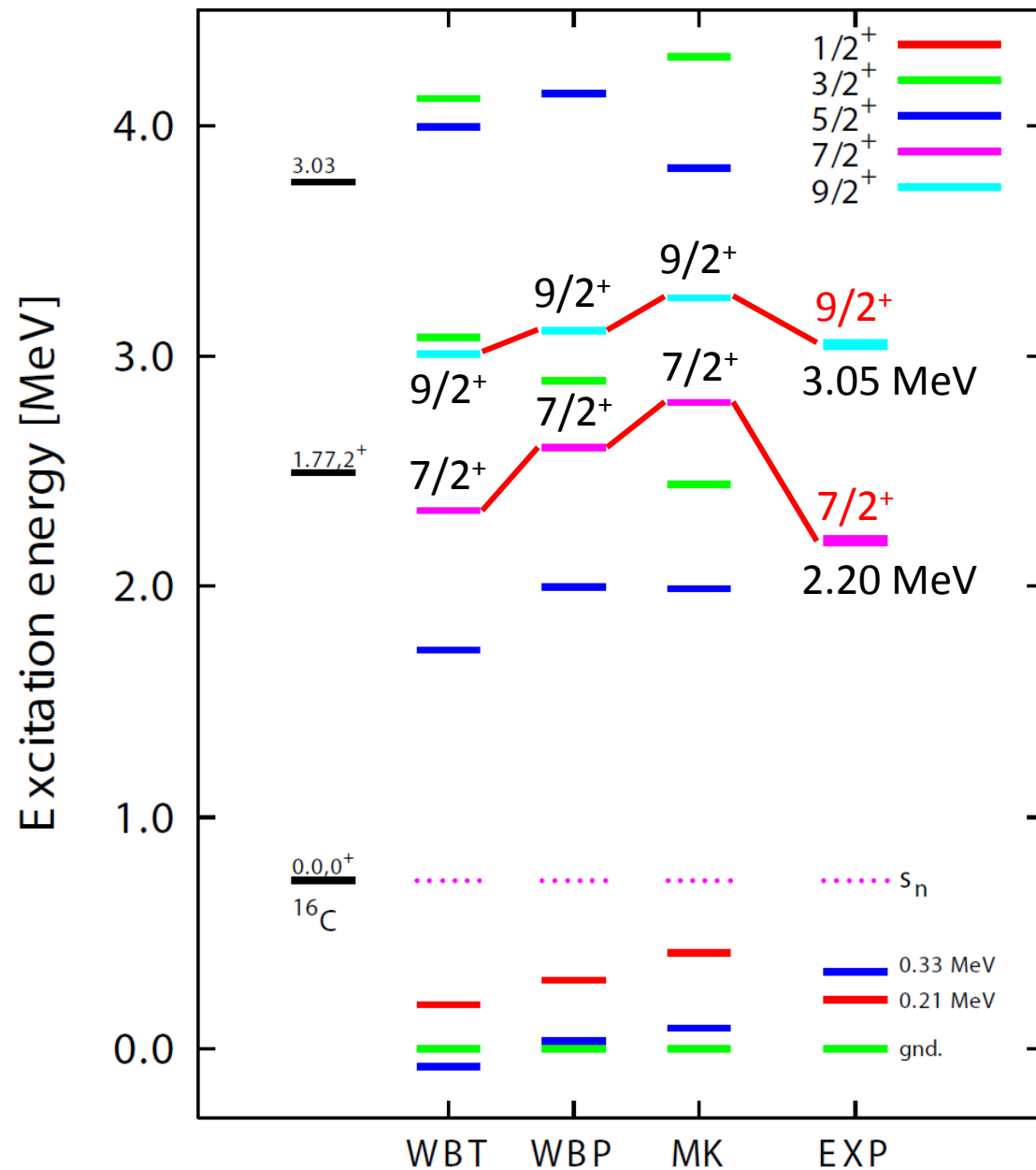


Optical potential: KD02, JLM(dotdashed)
Effective interaction: M3Y
Shell model: WBT

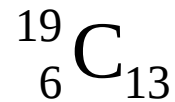
$$J^{\pi}_{\text{g.s.}} = 1/2^+$$



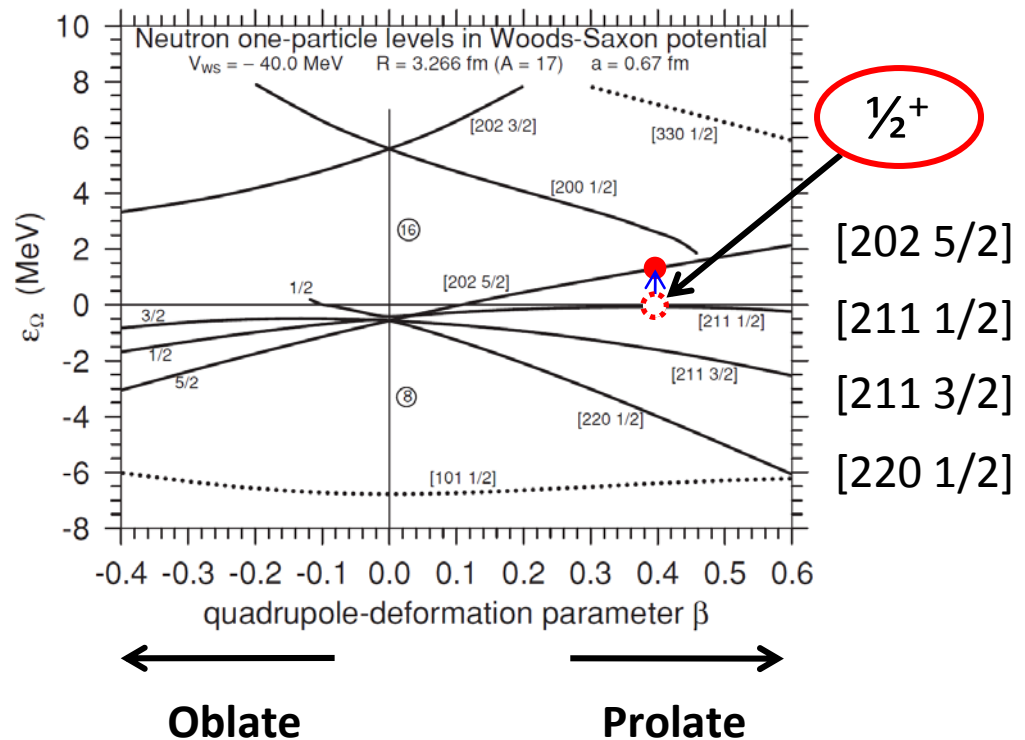
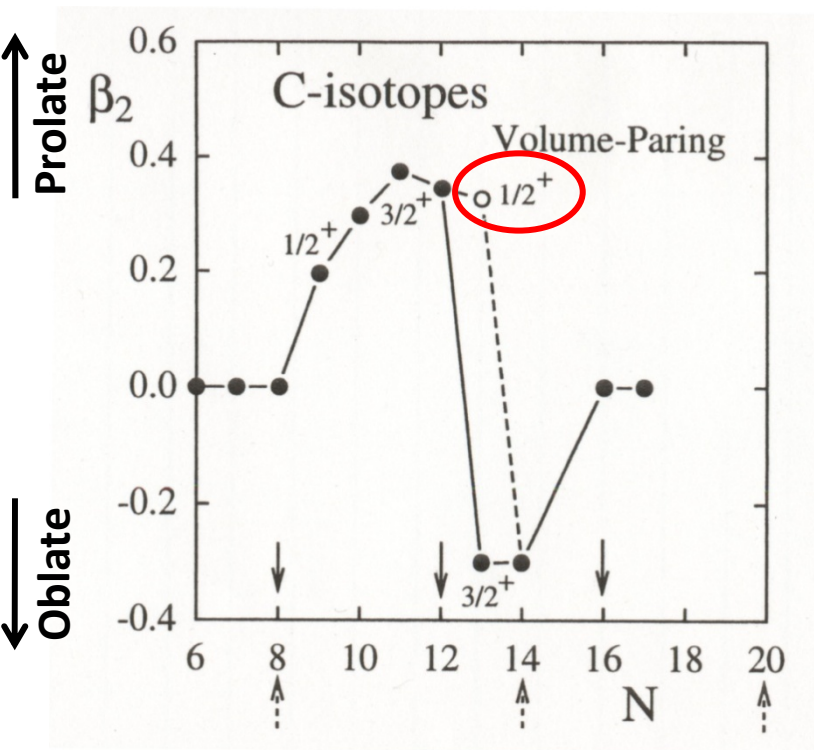
Energy level diagram of ^{17}C



c.f. H.G.Bohlen et al.,
Eur. Phys. J. A31, 279 (2007).



H.Hamamoto, PRC76(2007)054319.



- $J^\pi_{\text{g.s.}}({}^{19}\text{C}) = 1/2^+ \Rightarrow$ prolate deformation for the ground state
- No definite conclusion on the new shell closure at $N=16$ in C chain.
- Further studies needed.
 - Ex(2^+) in ${}^{22}\text{C}$ (with $N=16$) ?
 - Ex(2^+) in ${}^{24}\text{O}$ (with $N=16$) ? $\Leftarrow$ RIKEN R405, soon be ready

まとめ

- 逆運動学 $^{19,17}\text{C}(p,p')$ 反応を測定し、非束縛領域に共鳴準位を見出した。
- ^{19}C : 殻模型計算やDWBA 計算と実験結果(励起エネルギー、断面積)の比較により、共鳴、基底準位の $J^\pi(\text{g.s.})$ をそれぞれ次のように決定した。
 - $J^\pi(\text{g.s.})=1/2^+$, $J^\pi(1.46 \text{ MeV})=5/2^+$
- ^{17}C : 同様の解析により基底状態の J^π を次のように決定した。
 - $J^\pi(\text{g.s.})=3/2^+$
- 炭素同位体での新魔法数 $N=16$ の確固とした証拠は得られなかった。
- ドリップライン近傍核の核分光手段として、不変質量法を用いた陽子非弾性散乱は有用である。

$\text{Ex}(2^+)$ in ^{22}C ?

$\text{Ex}(2^+, 1^+)$ in ^{24}O ?

Collaborators (R364)

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