Tensor analyzing power of the $^{16}O(d,{}^{2}He)$ reaction at 0 degrees and structure of the spin-dipole resonances

Kenji Suda

Center for Nuclear Study, University of Tokyo

Contents

1. Introduction
2. Experiment
3. Results
4. Discussion
5. Summary

H. Okamura
Cyclotron and Radioisotope Center, Tohoku University

T. Uesaka, Y. Maeda
Center for Nuclear Study, University of Tokyo

R. Suzuki, H. Kumasaka, T. Ikeda, K. Itoh
Department of Physics, Saitama University

H. Sakai, K. Yako, M. Hatano, T. Saito, H. Kuboki
Department of Physics, University of Tokyo

A. Tamii
Research Center for Nuclear Physics, Osaka University

N. Sakamoto, K. Sekiguchi
The Institute of Physical and Chemical Research (RIKEN)

Y. Satou
Department of Physics, Tokyo Institute of Technology

Spin dipole resonance in nuclei

Spin Dipole Resonance (SDR)

$\Delta S = 1,\ \Delta T = 1, \Delta L = 1$

$J^\pi = 2^-, 1^-, 0^-$

cf. Giant Dipole Resonance

$\Delta S = 0,\ \Delta T = 1, \Delta L = 1$

$J^\pi = 1^-$

Physical aspects...

- **Quenching problem — c.f. Gamow-Teller resonances**
- **pion correlation in nuclei — 0^- state is of interest**
- **Neutrino (ν_μ, ν_τ) detection by using $^{16}O^*$(SDR)**

  K. Langanke *et al.*, PRL 76, 2629 (1996)

Spin dipole resonance in ^{16}O nucleus

^{16}O : doubly closed shell, $N = Z = 8$

spherical shape –
well described by shell model calc.

Calculation shows

$E_x(2^-) < E_x(1^-) < E_x(0^-)$

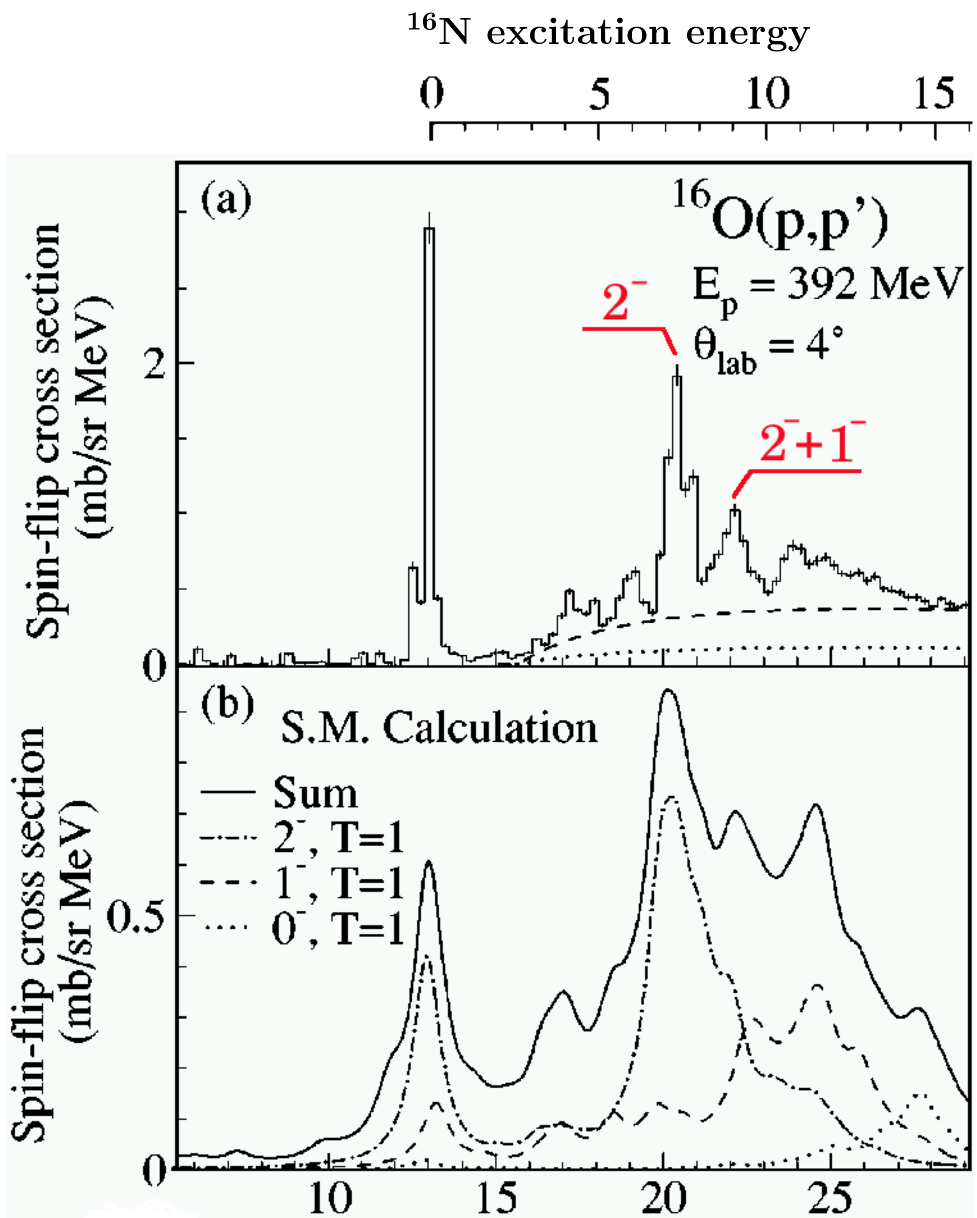
however,

$2^-, 1^-, 0^-$ states overlap each other

Difficulty in J^π assignment

For further study of SDR,
J^π assignment is essentially needed.

$\rightarrow$ the $(d, {}^2\mathrm{He})$ reaction at 0 degrees



T. Kawabata *et al.*, Phys. Rev. C 65, 064316 (2002).

The $(d, {}^2\mathrm{He})$ reaction

(n, p)-type charge exchange reaction

^{2}He : Two-proton system in ${}^1S_0$ state – strong correlation in FSI

Spin-Ispspin selectivity

	$d \longrightarrow {}^2\mathrm{He}$
spin S	$1 \longrightarrow 0$
isospin T	$0 \longrightarrow 1$

$\Delta T_z = +1$

Advantage compared with the (n, p) reaction

– high detection efficiency and resolution

– Exclusive spin-flip selectivity $\Delta S = 1$

– Tensor analyzing power A_{ij}

Characteristic behavior depending on spin-parity of residual nucleus

especially A_{zz} at 0 degrees

Tensor Analyzing power A_{zz} at 0 degrees

differential cross section at 0°

$$\left(\frac{d\sigma}{d\Omega}\right)_{pol}(0^\circ) = \left(\frac{d\sigma}{d\Omega}\right)_0(0^\circ)\left[1 + \frac{1}{2}p_{zz}A_{zz}(0^\circ)\right]$$

For the $1^+ + 0^+ \longrightarrow 0^+ + I^\pi$ type reaction,

due only to parity conservation

$$A_{zz}(0^\circ) = \begin{cases} +1 \text{ for } I^\pi = \text{(natutal parity)} \\ \qquad\qquad\qquad [\pi = (-)^I] \\ -2 \text{ for } I^\pi = 0^- \end{cases}$$

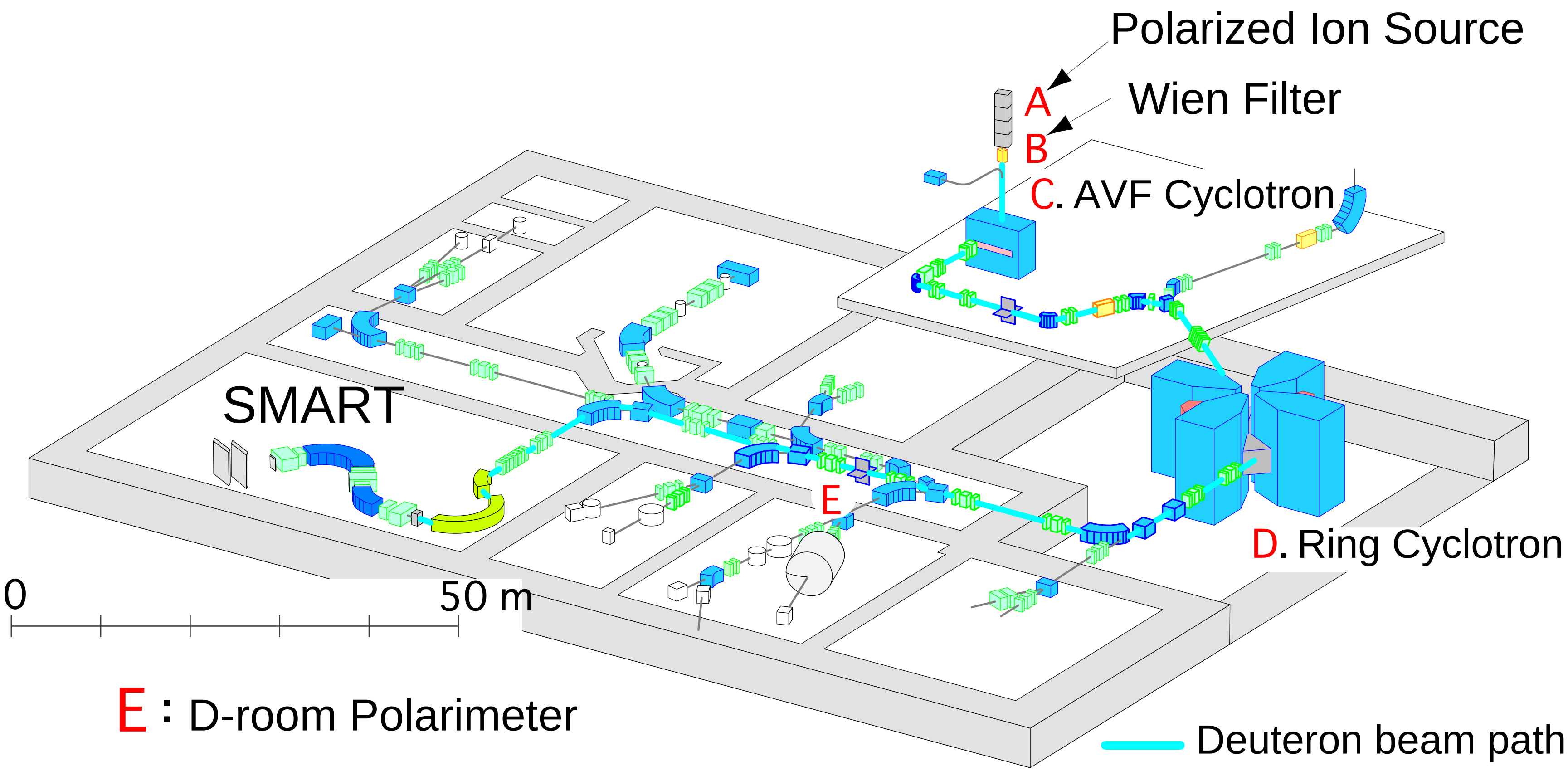
spin-parity can be determined model-independently

Successfully applied to ^{12}C nucleus

H. Okamura *et al.*, PRC 66, 054602 (2002)

$\longrightarrow$ apply to ^{16}O nulceus

RIKEN Accelerator Research Facility (RARF)



$(d, {}^2\mathrm{He})$ reaction — SMART spectrograph
beam polarization — D-room polarimeter

Conditions

Beam	deuteron
energy	270 MeV
current	0.3 nA
polarization	$P_{ZZ} = 0, -2, +1$ changed in every 5 sec.

SMART spectrograph

The first focal plane primarily for the $(d, {}^2\mathrm{He})$ measurement

- large acceptance

  $\Delta\Omega = 13.1$ msr

- medium momentum resolution

  $\Delta p/p = 1.2 \times 10^{-3}$

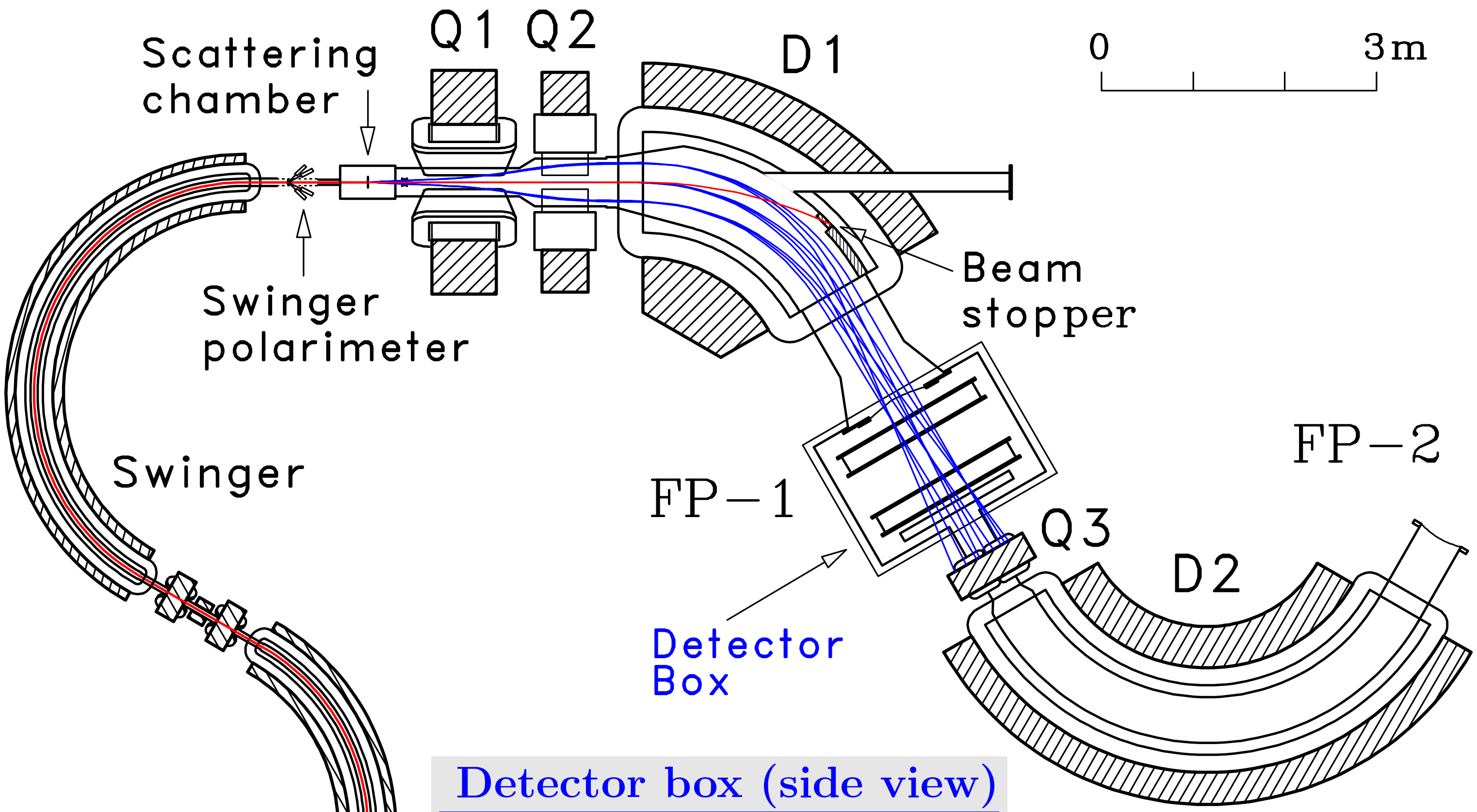
- ^{2}He overall angular resolution

  $\Delta\theta = 9$ mrad

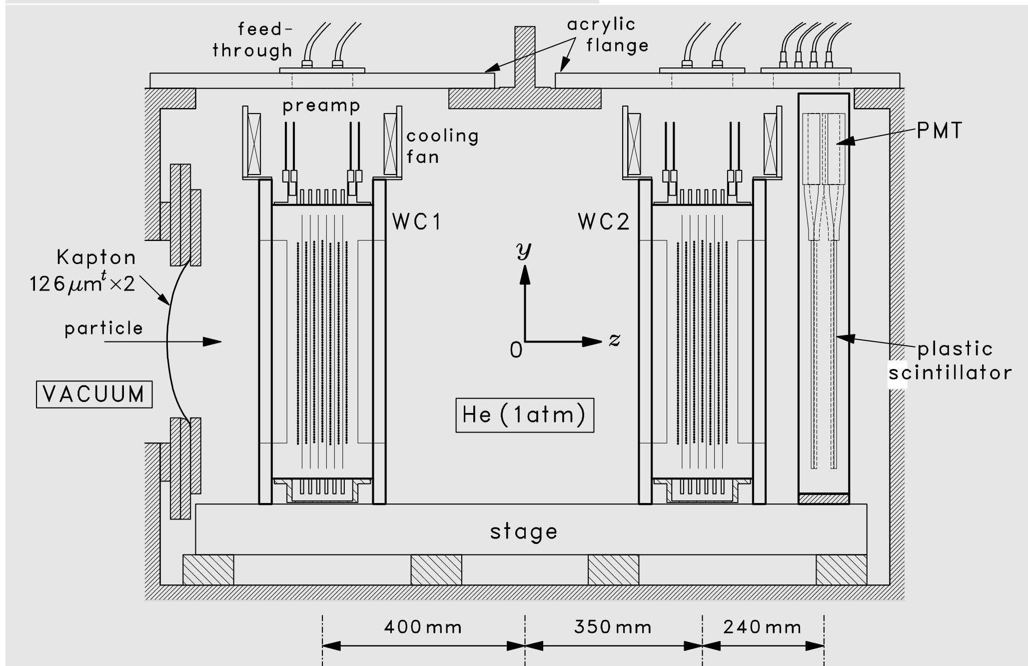
Target: Solid Oxygen
$5 - 40$ mg/cm^2

RIKEN Accel. Prog. Rep. 36, 188 (2003)

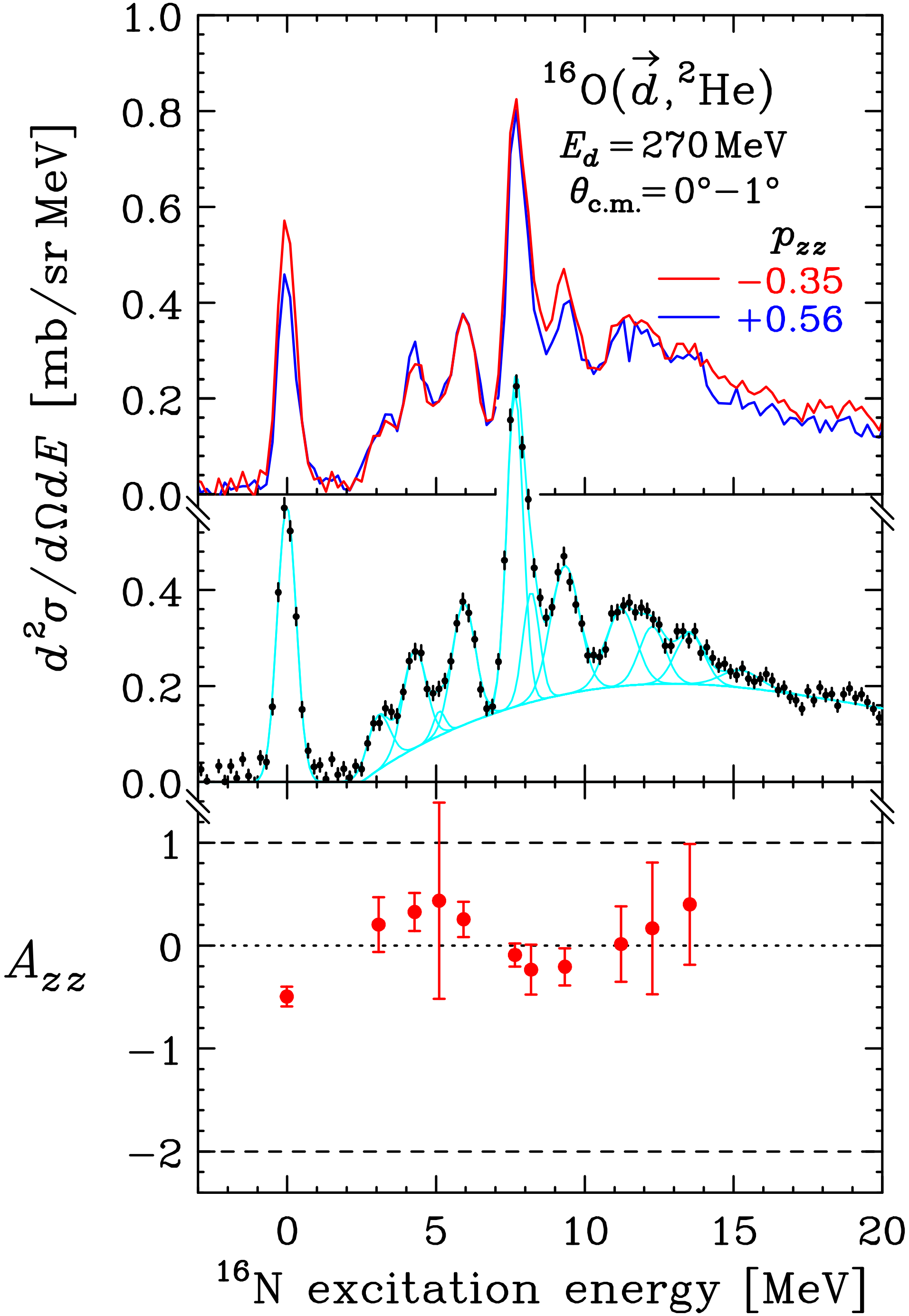
angular range: $\theta_{\mathrm{c.m.}} = 0^\circ - 4^\circ$

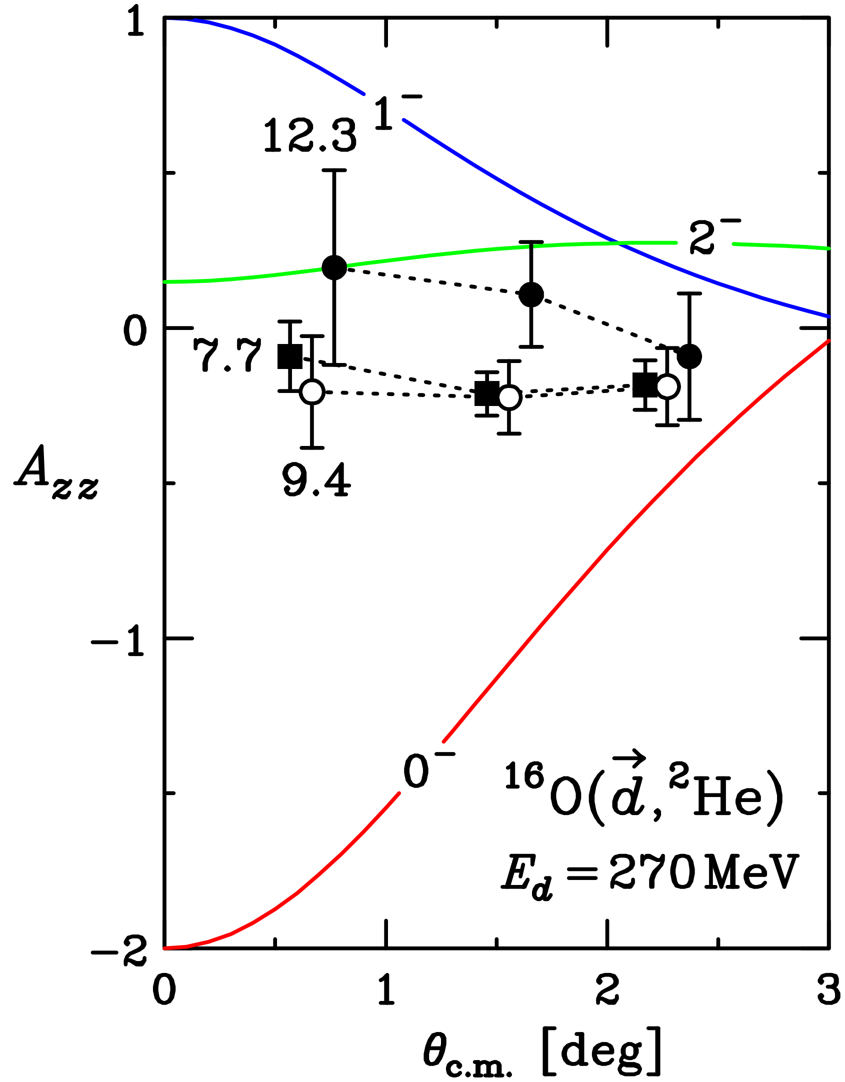


Detector box (side view)



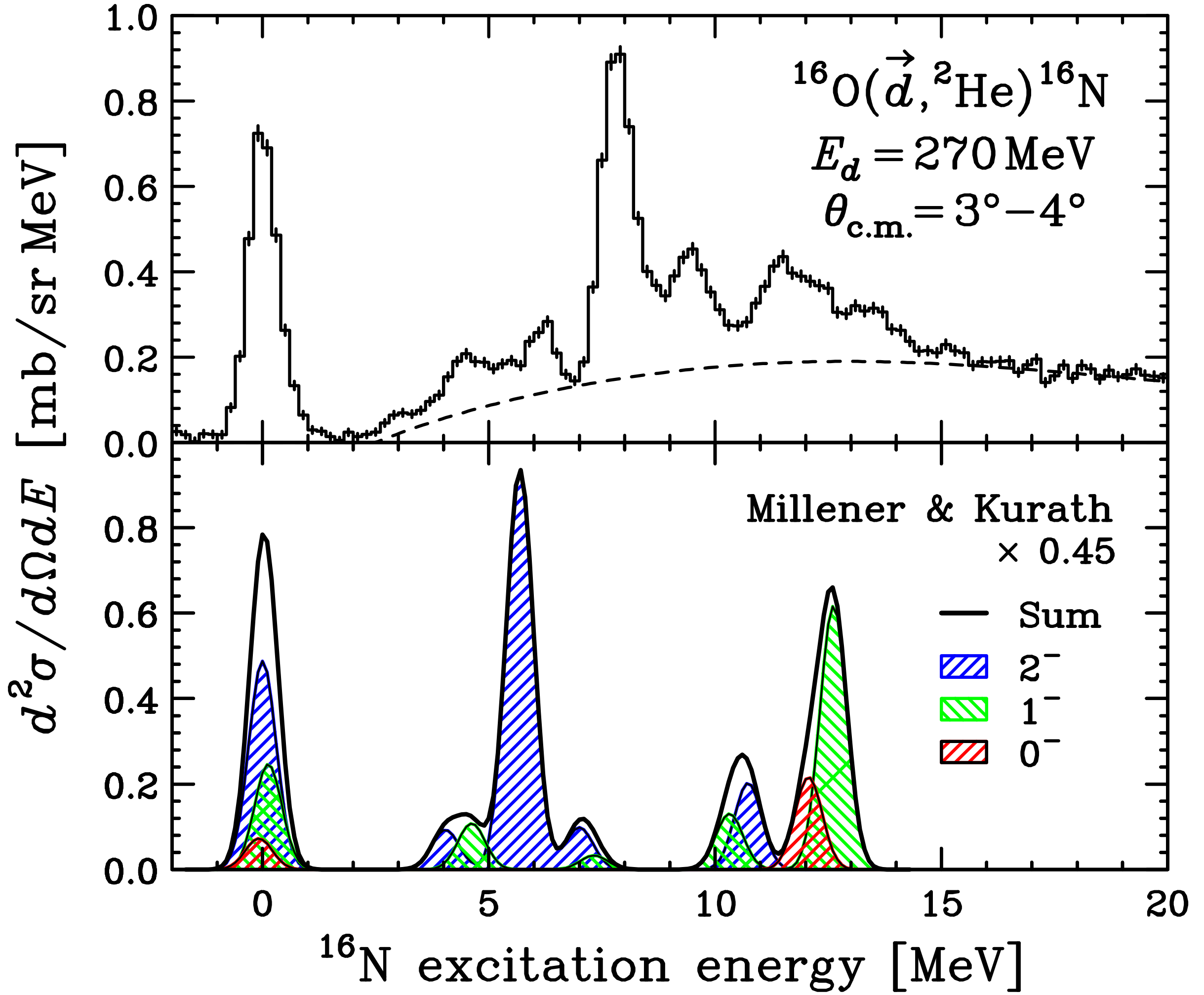
Results





Bump at 7.7 MeV — 2^- dominant

Comparison with shell-model calculation



7.7 MeV (exp.) ⇔ 2^- state at 6 MeV (calc.)

concentration of 1^- state

– not observed at $E_x \sim 12$ MeV

Summary

In order to study the structure of Spin dipole resonance,

We performed the measurement of

the $^{16}O(d,{}^{2}He)^{16}N$ reaction at 0°, $E_d = 270$ MeV

Model-independent spin-parity determination method using tensor analyzing power $A_{zz}(0^\circ)$ was applied

- Bump at $E_x = 7.7$ MeV is confirmed to be dominated by 2^- states
  – consistent with shell model calculation

- No observation of concentrated 1^- states at $E_x \sim 12$ MeV

Theoretical calculation for the $(d, {}^2\mathrm{He})$ reaction

Adiabatic Coupled-channels Born Approximation (ACCBA) calculation

H. Okamura, Phys. Rev. C 60, 064602 (1999).

Dynamics of the final state p-p-(residual) system is treated by a method based on the adiabatic approximation

— parameter free method

$\Leftrightarrow$ uncertainty of ^{2}He optical potential (in DWBA)

Parameters

NN effective interaction

Franey & Love, 140 MeV, PRC 31, 488 (1985).

Spectroscopic factors

calculated by shell model code OXBASH

minus parity states — Millener & Kurath wave func.
psd shell-space ($1\hbar\omega$)

Single particle wave functions

calculated by using Woods-Saxon type potential