

Proton resonance elastic scattering of ^{32}Mg for single particle structure of ^{33}Mg

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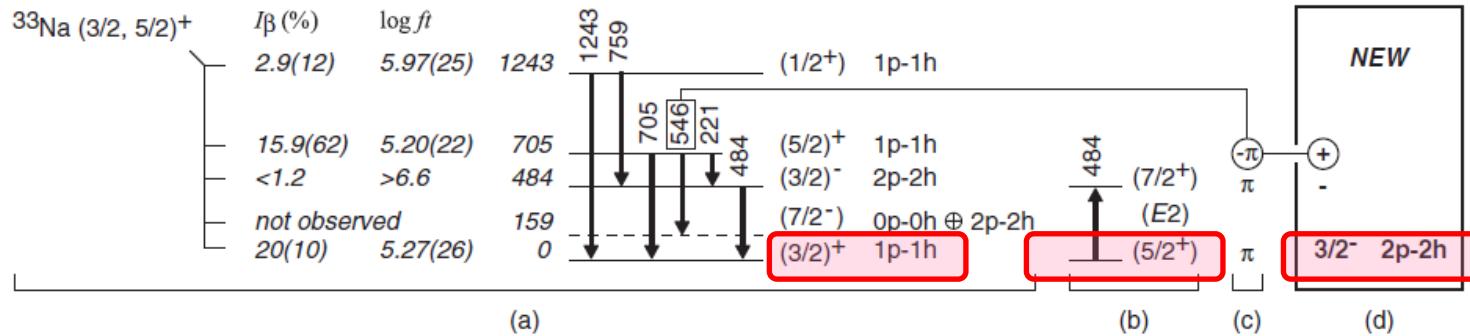
CERN: J. Kurocewicz

Kyusyu-U: T. Teranishi

CNS, Univ. o Tokyo: D. Kahl, H. Yamaguchi

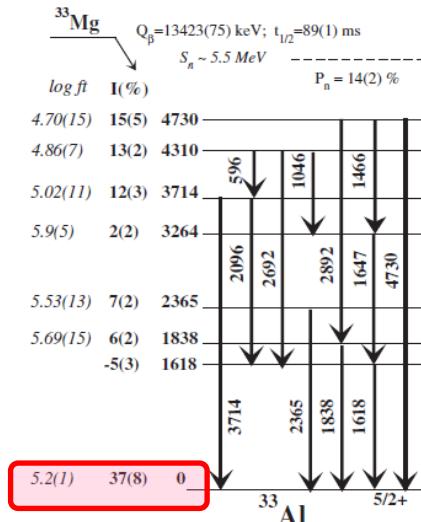


Inconsistency of J^π for $^{33}\text{Mg}_{\text{g.s.}}$



D. T. Yordanov, et al., PRL99, 212501

$$\mu/\mu_n = -0.7456(5)$$

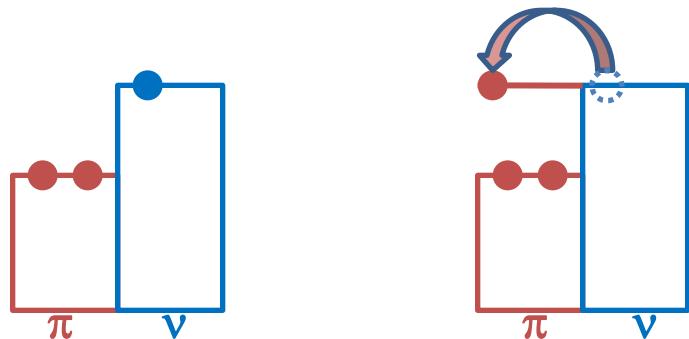


The β decay of ^{33}Mg ($N = 21$) presented in this Letter reveals intruder configurations in both the parent and the daughter nucleus. The lowest excited states in the $N = 20$ daughter nucleus, ^{33}Al , are found to have nearly $2p - 2h$ intruder configuration, thus extending the “island of inversion” beyond Mg. The allowed direct β -decay branch to the $5/2^+$ ground state of the daughter nucleus ^{33}Al implies positive parity for the ground state of the parent ^{33}Mg , contrary to an earlier suggestion of negative parity from a g-factor measurement. An admixture of $1p-1h$ and $3p-3h$ configurations is proposed for the ground state of ^{33}Mg to explain all of the experimental observables.

V. Tripahi, et al., PRL101, 142504



Isobaric Analog Resonances of bound states of ^{33}Mg



Parent state

IAS

$$\phi_{\text{core}} \phi_v \quad \phi_v = \phi_\pi \quad \phi_{\text{core}} \phi_\pi$$

Resonance shape

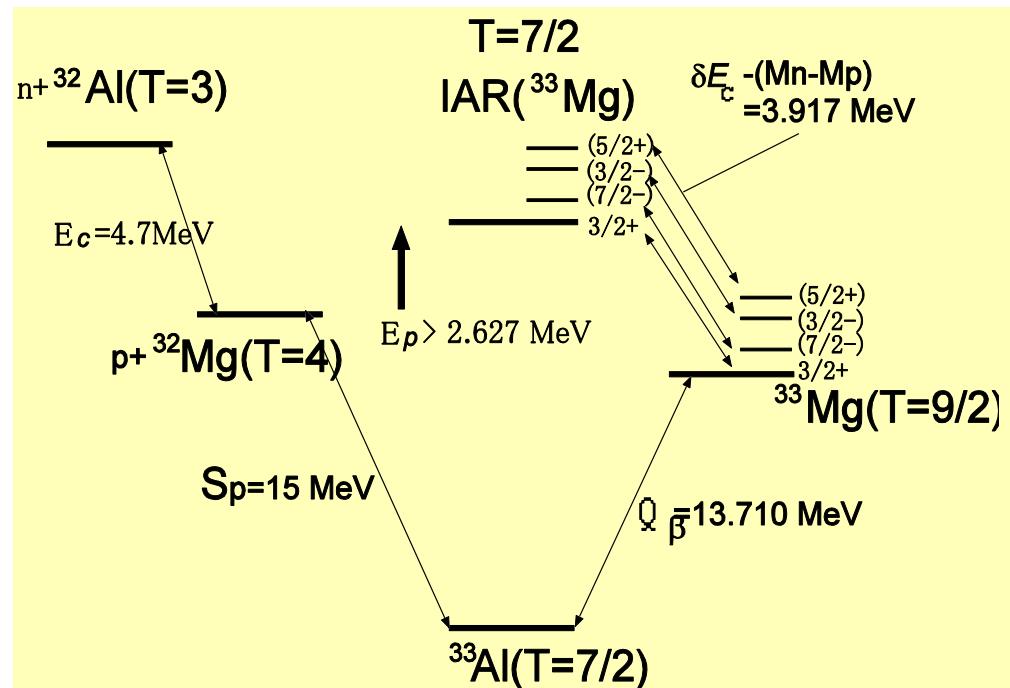
= angular momentum (I)

Resonance width

= total width (Γ_{tot})

Resonance height

= proton width (Γ_p) $\sim S^{pp}$



Thick target inverse kinematics(T^2 IK) proton resonance elastic scattering with RIBs

Excitation function of $d\sigma/d\Omega(\theta_{\text{lab.}} \sim 0)$

cf.) V.Z. Goldberg, ENAM98

1. High-energy recoil proton

$\sim 4x E_{\text{reso}}$

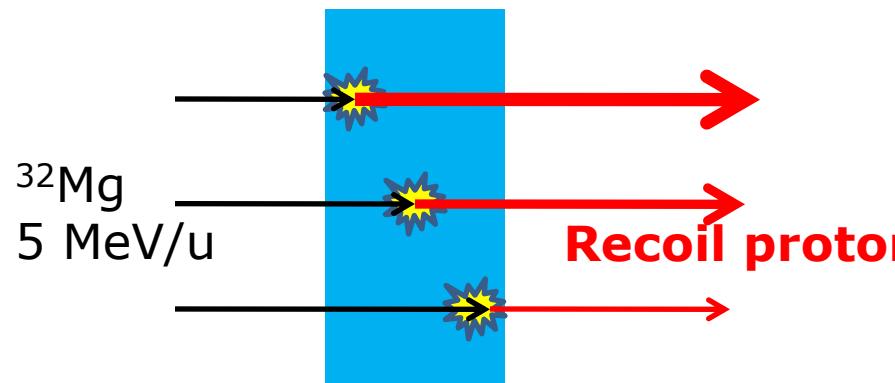
2. One fixed energy

3. Large cross section

$\sim \text{several } 10 \text{ mb/sr}$



Easy identification of resonances

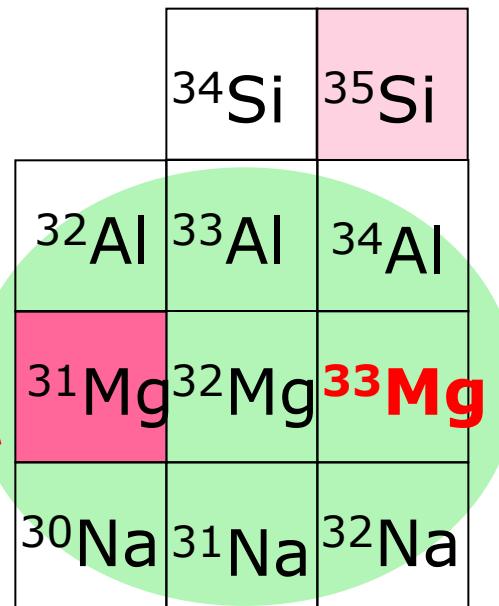
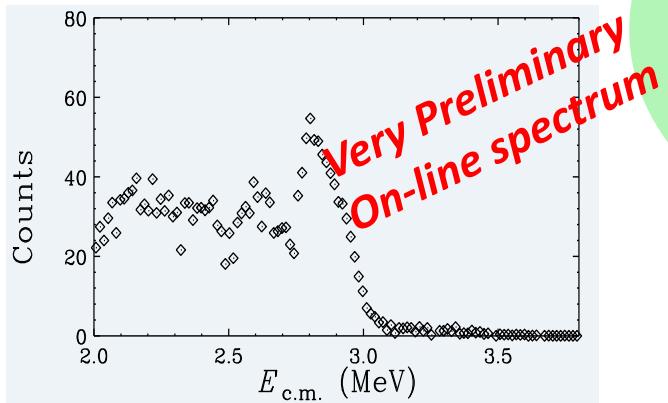
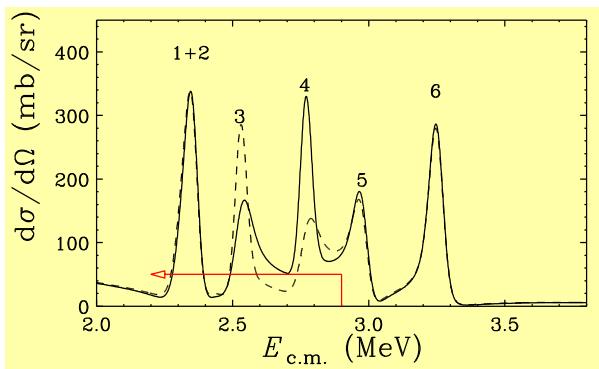


Thick hydrogen
Target (CH_2)



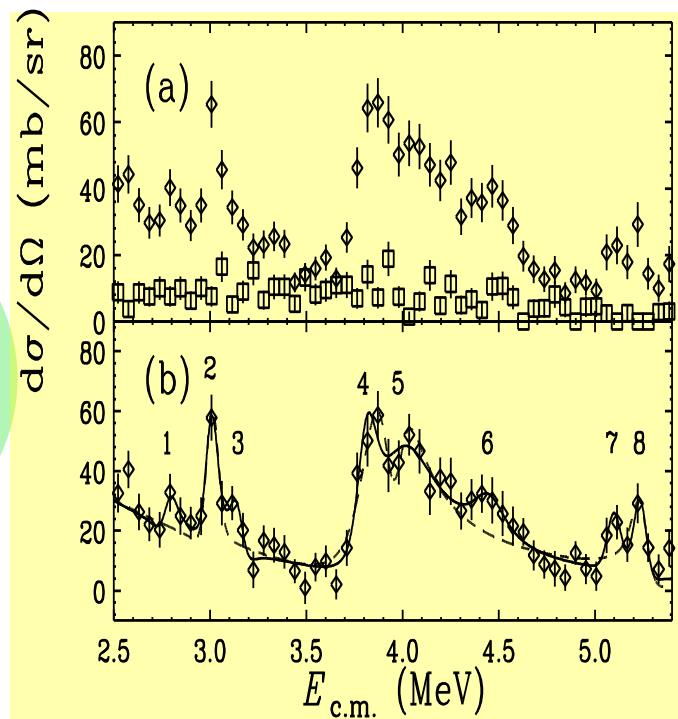
IAR measurements around ^{32}Mg

IS526: IAR of ^{31}Mg : $p(^{30}\text{Mg}, p)$ @REX-ISOLDE



IAR of ^{35}Si : $p(^{34}\text{Si}, p)$ @RIKEN

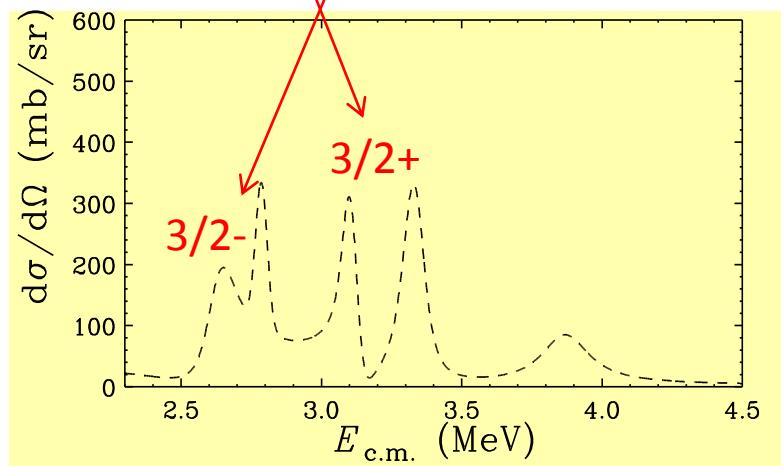
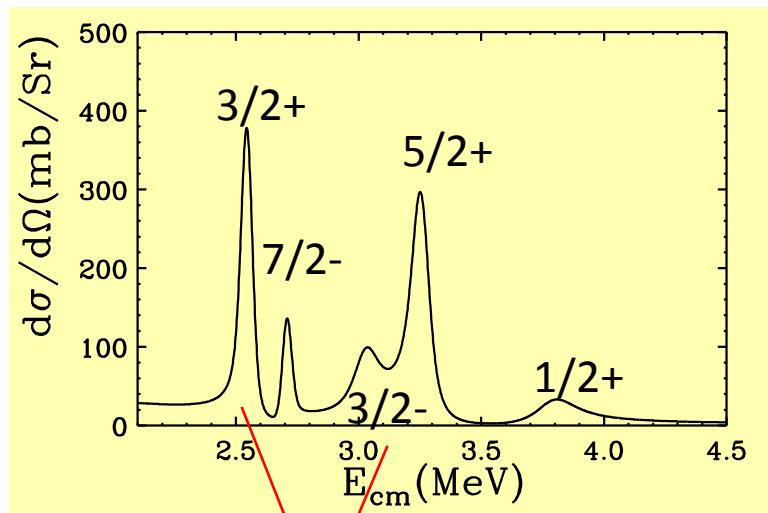
N. Imai et al., PRC85, 034313



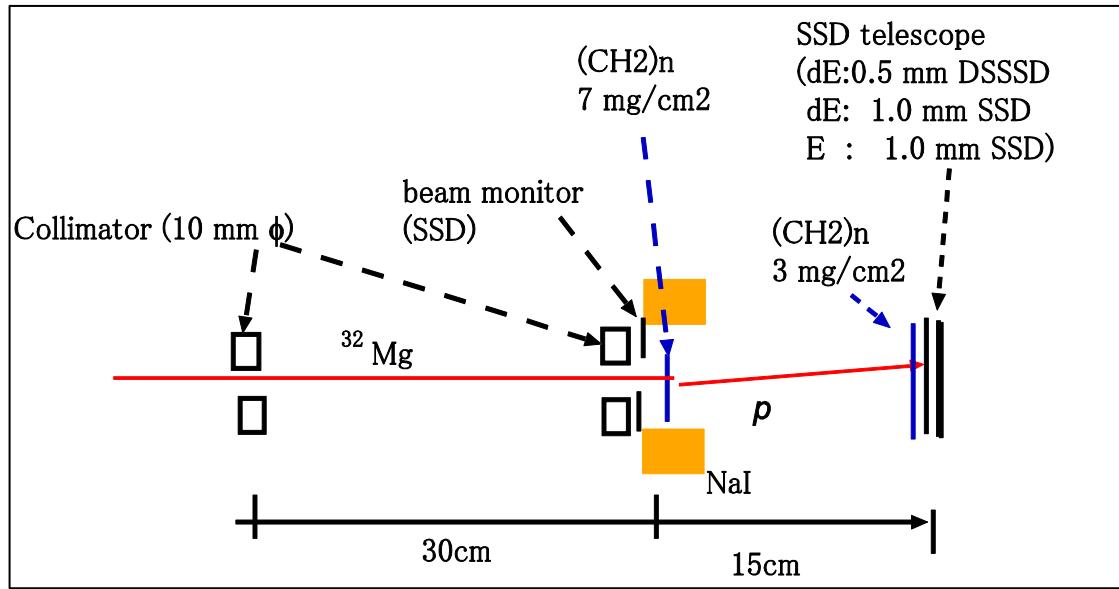
Expected excitation function of $p(^{32}\text{Mg}, p)$

$S=0.3$ was assumed.

| # | Ex (keV) | J^π | E_{cm} (MeV) | Γ_p (keV) |
|---|-------------|-----------|--------------------------|---------------------|
| 1 | 0. | $(3/2)^+$ | 2.627 | 26. |
| 2 | 160. | $(7/2^-)$ | 2.787 | 5.3 |
| 3 | 480. | $(3/2)^-$ | 3.107 | 111 |
| 4 | 710 | $(5/2)^+$ | 3.337 | 68. |
| 5 | 1240 | $(1/2^+)$ | 3.867 | 194. |



Experimental setup



Target: 100 μm ($\sim 10\text{mg}/\text{cm}^2$) thick CH₂ target
10 mg/cm² C target

Detector: dE-E annular (0.5+ 1.0 + 1.0 mm)
cf.) Highest E_p is 18 MeV

Absolute σ : off-resonance cross sections

Yield Estimation

- $d\sigma/d\Omega \sim 80 \text{ mb/sr}_{\text{lab.}}$ (off-resonance)
- $d = 39 \mu\text{g/cm}^2$ (20 keV/u-loss of ^{32}Mg in CH_2)
- $I = 1 \times 10^4 \text{ pps}$ O.T. Niedermaier, PhD thesis.
- $\Delta S = 110 \text{ msr}$

25 counts/day/20keV_{cm}-bin for off-resonance

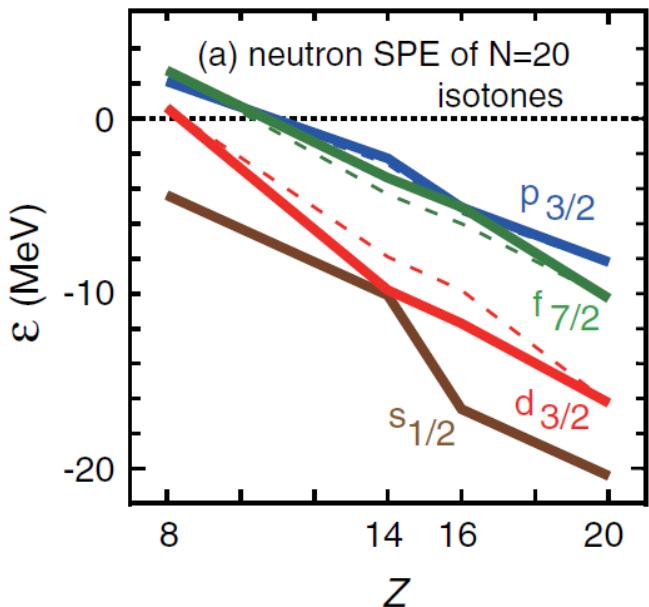


Beam time request

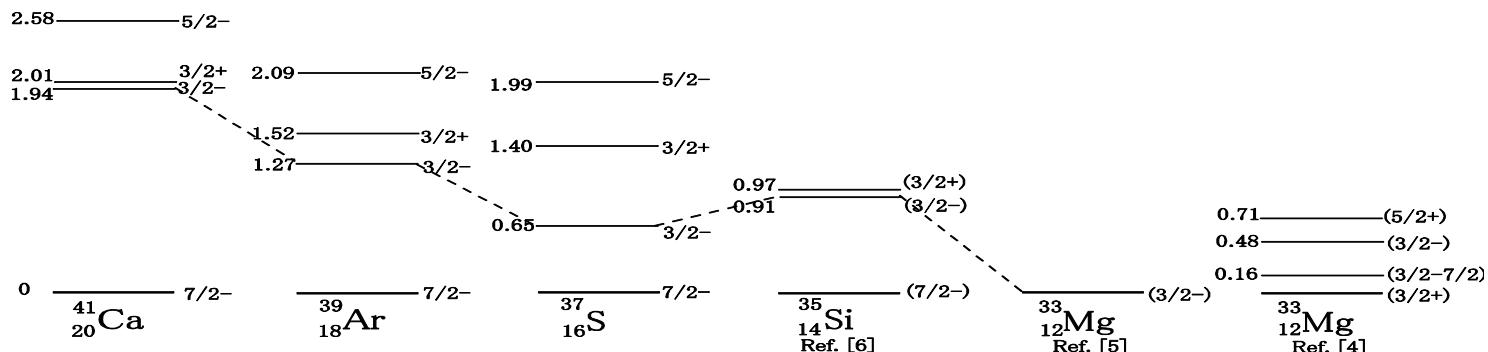
| | |
|--|--------------------------|
| IAR measurements w/ stable ^{26}Mg beams including circuit tuning | 2 shifts |
| IAR measurements w/ CH_2 w/ ^{32}Mg | 12 shifts (laser-on/off) |
| BG runs w/C target w/ ^{32}Mg | 6 shifts (laser-on/off) |
| total | 20 shifts |



Single particle energies at ‘Island of inversion’



T. Otsuka et al, PRL104,012501



Contamination in beam

Ex. $^{32}\text{Mg}^{9+}$: 85%, $^{32}\text{Al}^{9+}$:12%, $^{32}\text{S}^{9+}$:2.6 %

O.T. Niedermaier, PhD thesis.

- Stripper foil will be test to make fully-stripped beams
ex. 1.0 μm C: $^{32}\text{Mg}^{9+}$ 5MeV/u \rightarrow $^{32}\text{Mg}^{12+}$ 4.94 MeV/u



Collaboration

- KEK : N.I., Y. Hirayama, H. Ishiyama, S.C. Jeong, M. Mukai, H. Miyatake, Y.X. Watanabe
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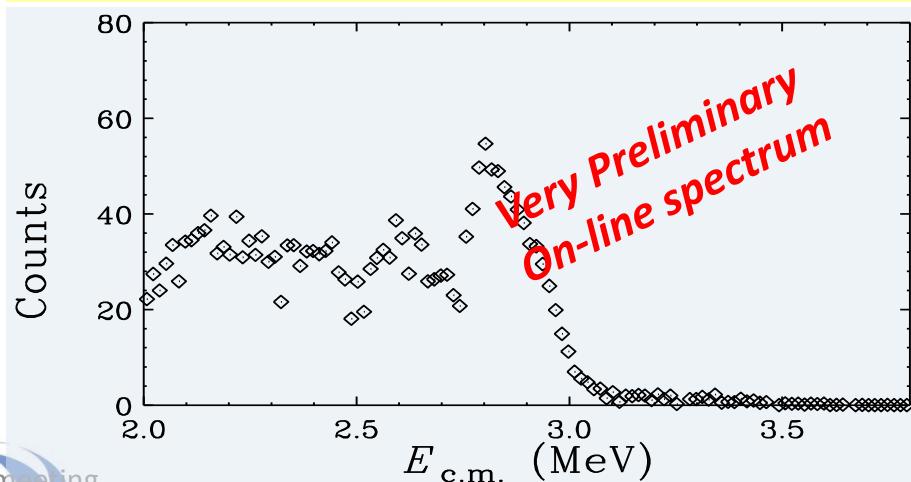
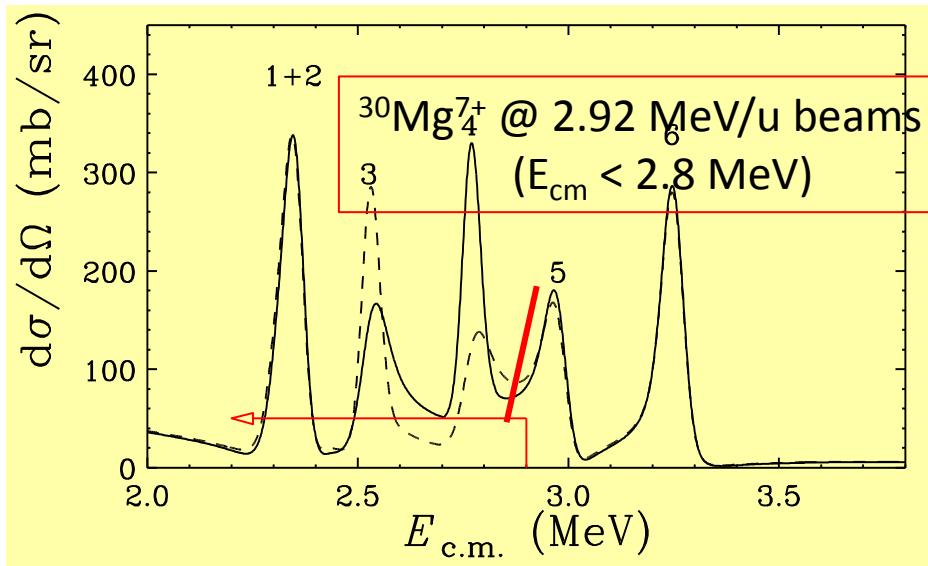


IS526: $p(^{30}\text{Mg}, p)$ @REX-Isolde

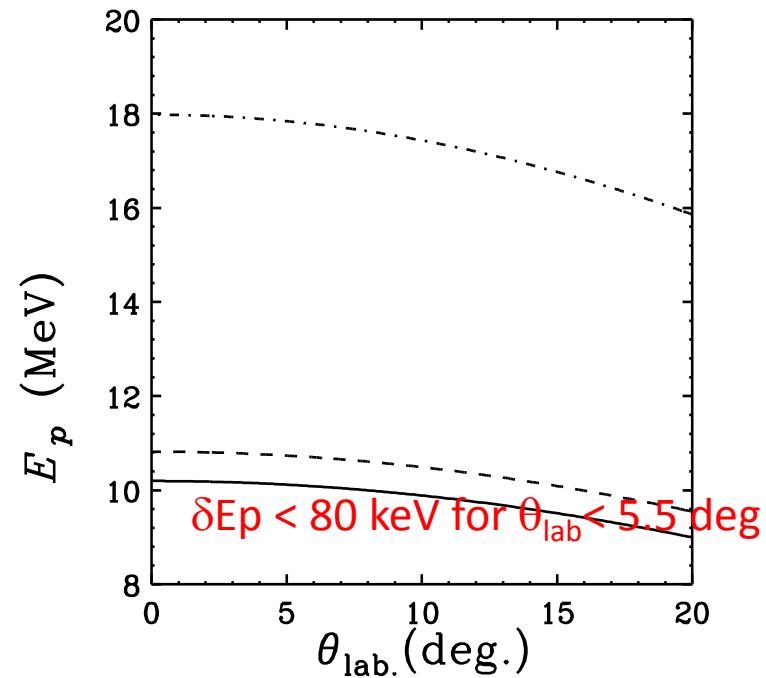
N. Imai, J. Cederkall et al.,

Expected resonance parameters
S=0.3 was assumed.

| # | Ex (keV) | J^π | E_{cm} (MeV) | Γ_p (keV) |
|---|----------|-----------|-----------------------|------------------|
| 1 | 0. | $1/2^+$ | 2.307 | 57. |
| 2 | 50. | $(3/2^+)$ | 2.357 | 11. |
| 3 | 221. | $(3/2^-)$ | 2.528 | 50. |
| 4 | 461. | $(7/2^-)$ | 2.768 | 6. |
| 5 | 673. | $(3/2^+)$ | 2.980 | 27. |
| 6 | 945. | $(5/2^+)$ | 3.252 | 27. |



- Fin



(d,p) vs Isobaric Analog Resonance

- (d,p) reaction

- Direct measurement

- wide angular distribution of $d\sigma/d\Omega$

- $d\sigma/d\Omega$ @ forward angle

- $\delta E_{\text{lab.}} \sim 1/3 \delta E_{\text{c.m.}}$

- γ -ray : suffer from decay scheme

- (p,p) resonance scattering

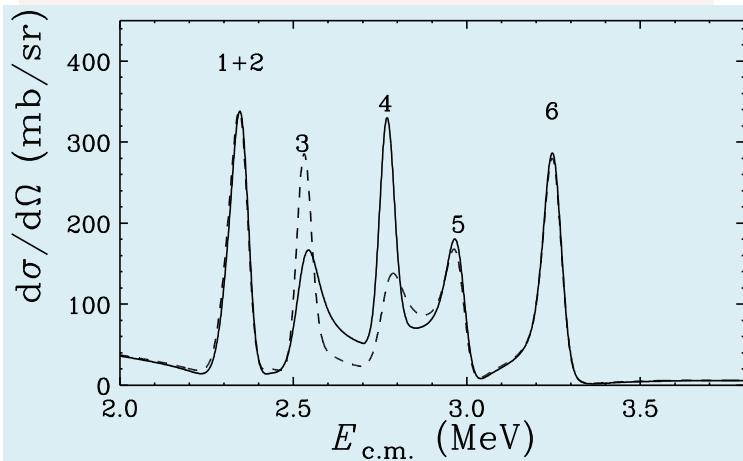
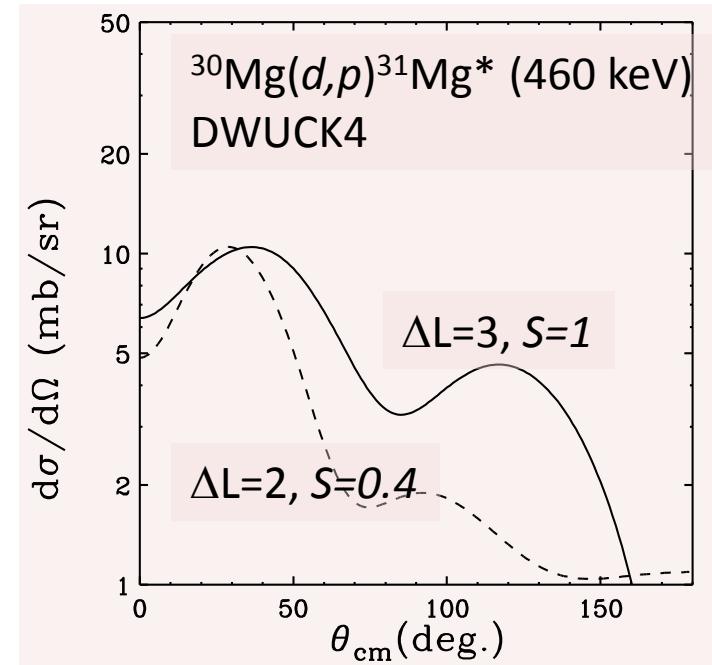
- Indirect measurement

- excitation function of $d\sigma/d\Omega$

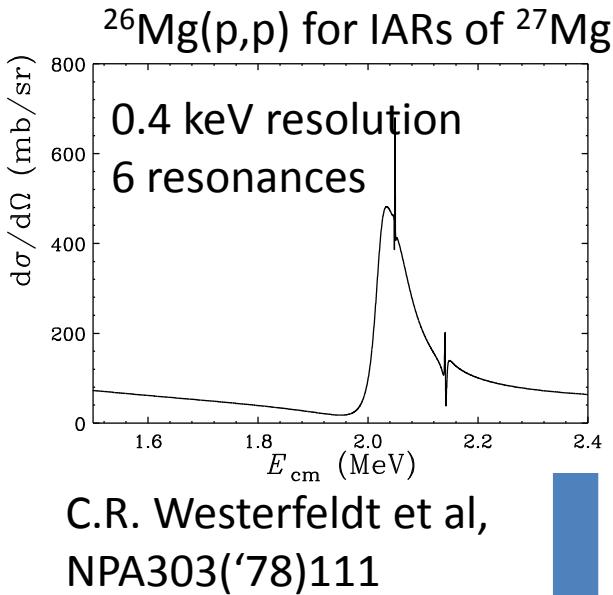
- $d\sigma/d\Omega$ @ backward angle ~ 180 deg_{c.m.}

- $\delta E_{\text{lab.}} \sim 4 \delta E_{\text{c.m.}}$

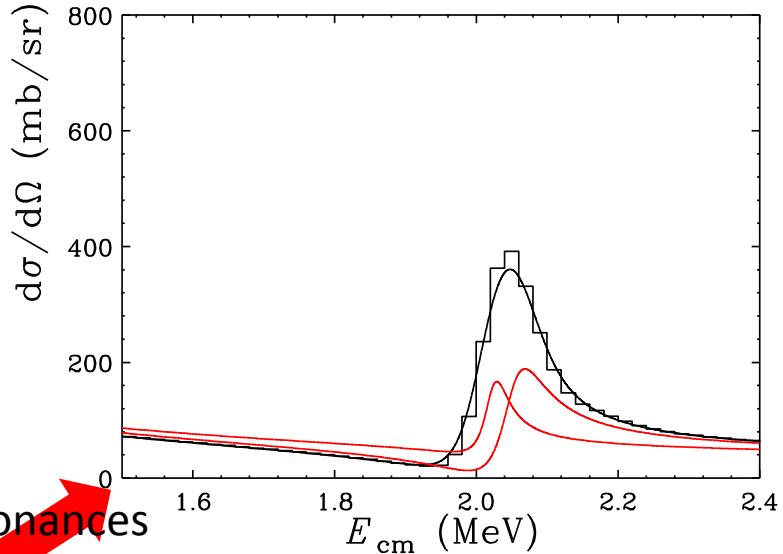
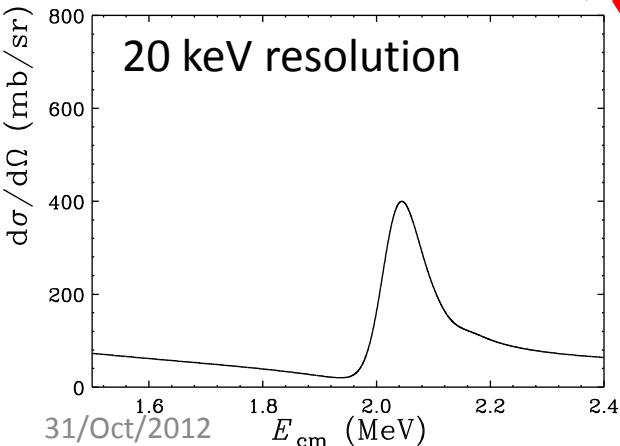
- Lower isospin excitation sometimes problem



Effect of T_c excitation



Fit with 2 resonances
($l=1$, and 0)



| # | Γ_p (keV) | E(keV) | J^π | Γ_p^{fit} | Γ_t^{fit} | $E^{\text{fit}}(\text{keV})$ |
|---|------------------|--------|---------|-------------------------|-------------------------|------------------------------|
| 1 | 40.9 | 2022.2 | $3/2^-$ | 50.2(43) | 57.1(23) | 2015(2) |
| 2 | 0.130 | 2047.9 | $3/2^+$ | - | - | - |
| 3 | 70.4 | 2049.2 | $1/2^+$ | 66.4(33) | 66.4(162) | 2051(3) |
| 4 | 0.075 | 2049.3 | $7/2^-$ | - | - | - |
| 5 | 1.1 | 2140.4 | $3/2^+$ | - | - | - |
| 6 | 5.6 | 2141.8 | $1/2^-$ | - | - | - |

43rd INTC-meeting



Estimation of Γ_p

- R-matrix theory

$$\Gamma_p = \left[\frac{S_{pp} P_l e^{-2\delta} \hbar^2 u_n^2(r)}{(N - Z + 1) \mu r} \right]_{r=a_c}$$

- ${}^{30}\text{Mg}(2^+)$: Ex. 1482 keV