Isoscalar excitations in ^{14}O

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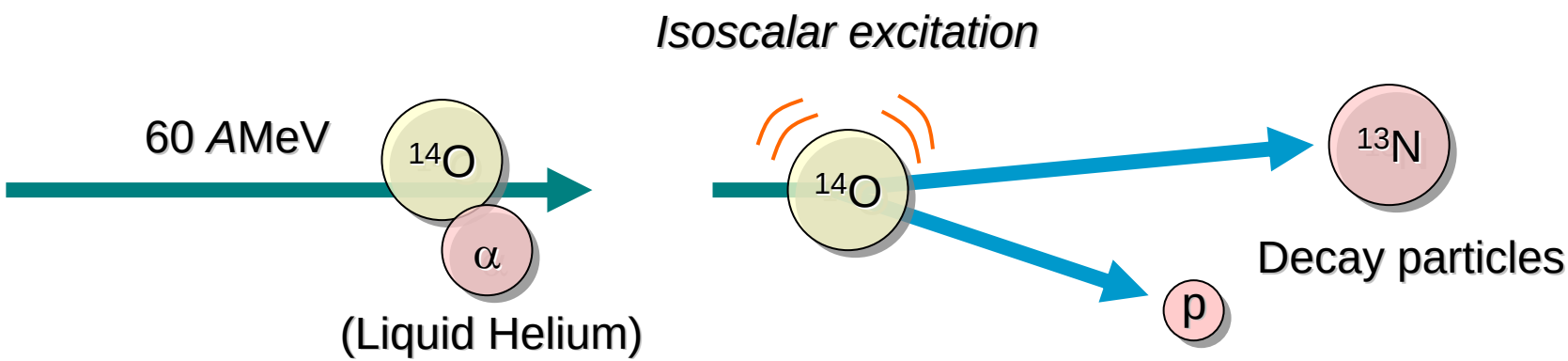
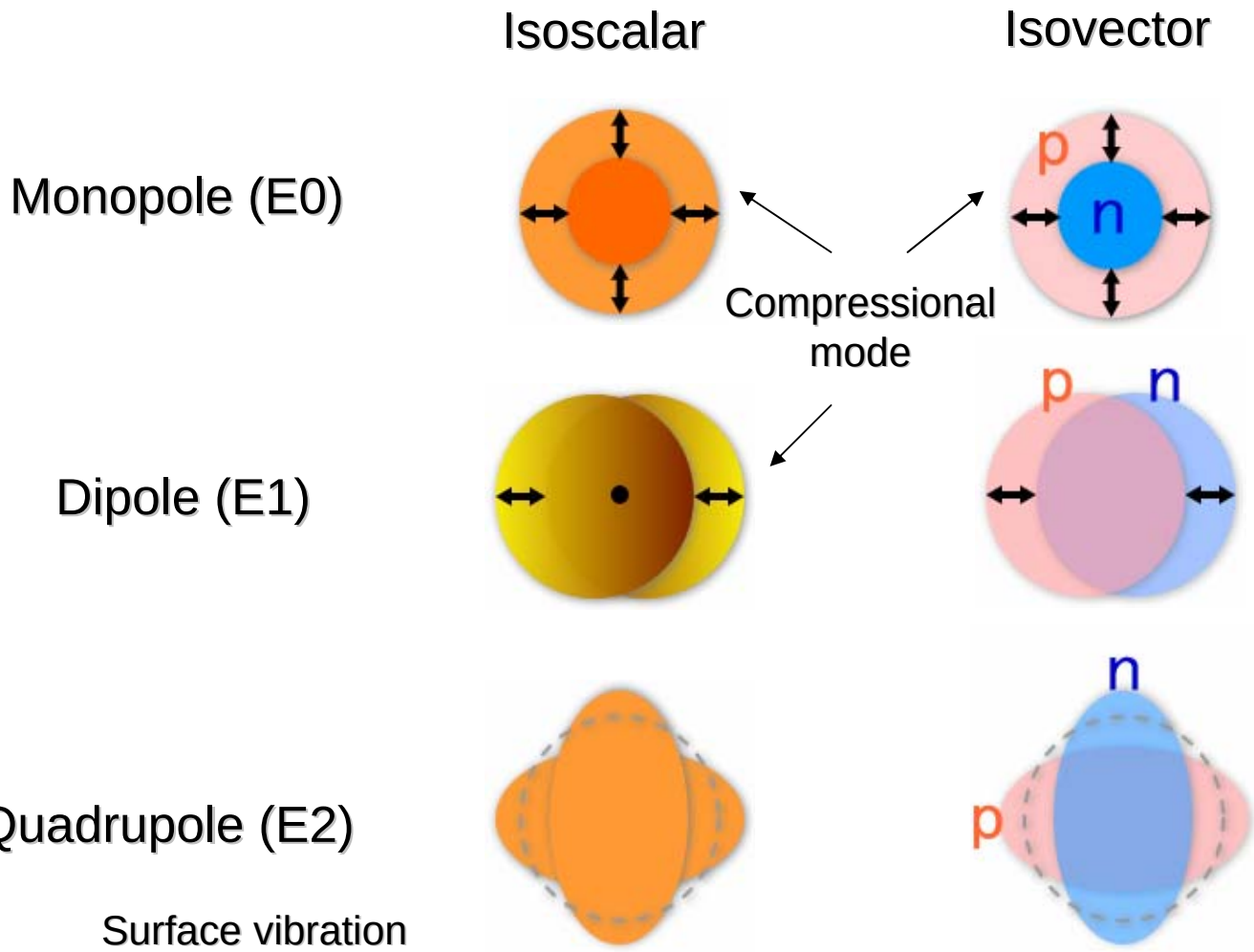
Outline

- Inelastic alpha scattering on ^{14}O
- Measure multiple decay particles and γ rays
  - Excitation energy = Invariant-mass
- Strength distributions
  - Multipole decomposition analysis (DWBA)
  - Isoscalar monopole, Isoscalar dipole



Collective excitations

- Macroscopic picture

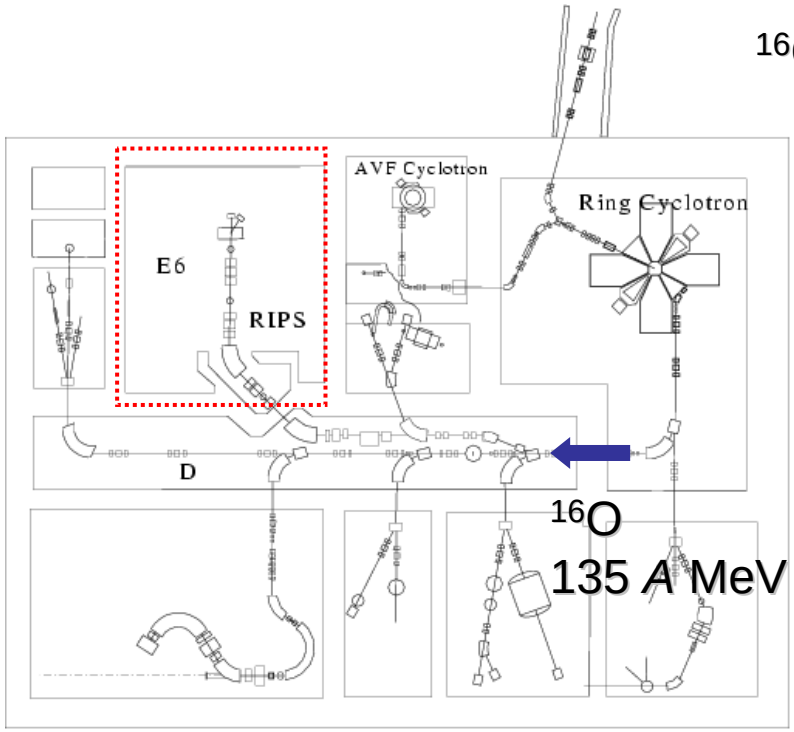


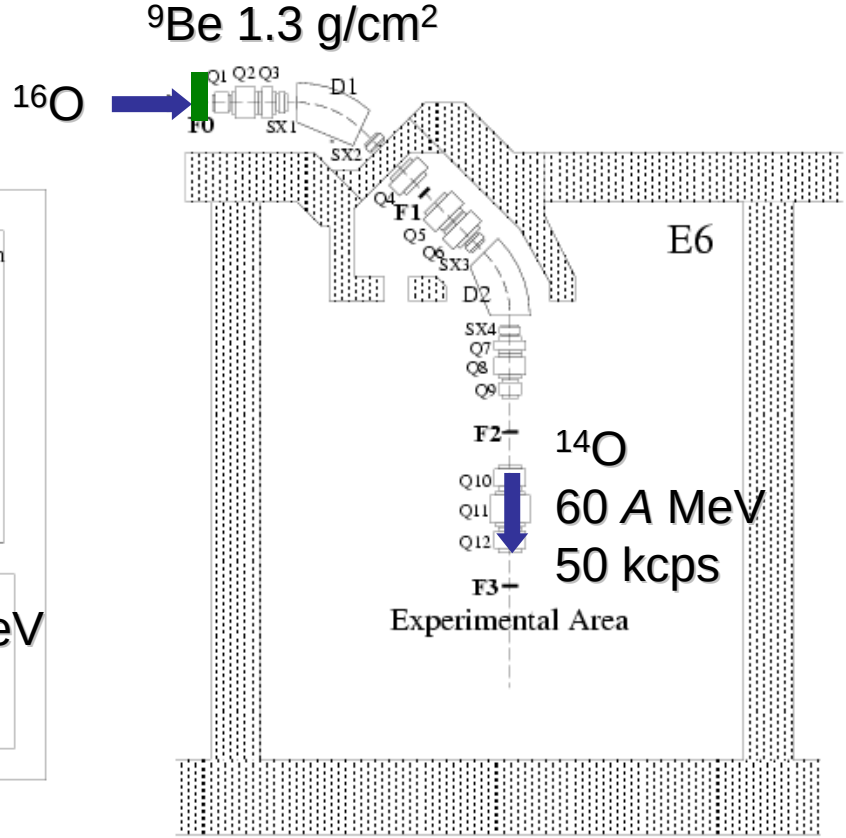
Inelastic α scattering on even-even nucleus

- Isoscalar natural parity states only
  - $J^{\pi} = L^{(-1)^L}$
  - It is possible to discriminate multipole from angular distribution

Inelastic scattering		Isoscalar Non-spin-flip	Isovector Non-spin-flip	Isoscalar Spin-flip	Isovector Spin-flip
alpha		●	—	—	—
proton		●	●	●	●
deuteron		●	—	●	—
Coulomb		—	●	—	—

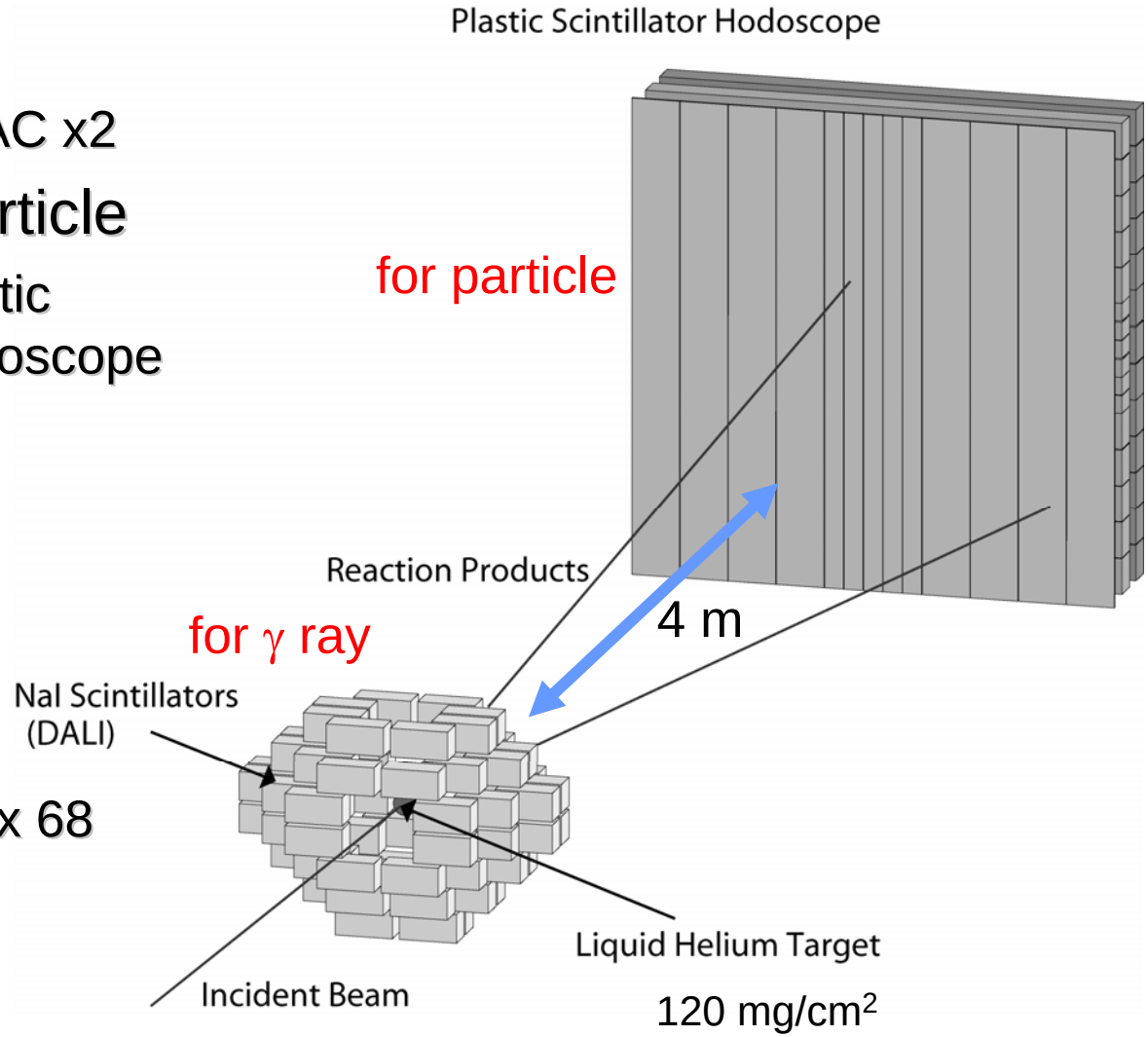
RIKEN RIPS


AVF Cyclotron
Ring Cyclotron
E6
RIPS
D
^{16}O
135 *A* MeV


^{9}Be 1.3 g/cm^2
^{16}O
Q1 Q2 Q3
D1
F0
SX1
SX2
Q4
F1
Q5
Q6
SX3
D2
E6
SX4
Q7
Q8
Q9
F2
^{14}O
60 *A* MeV
50 kcps
Q10
Q11
Q12
F3
Experimental Area

Experimental setup

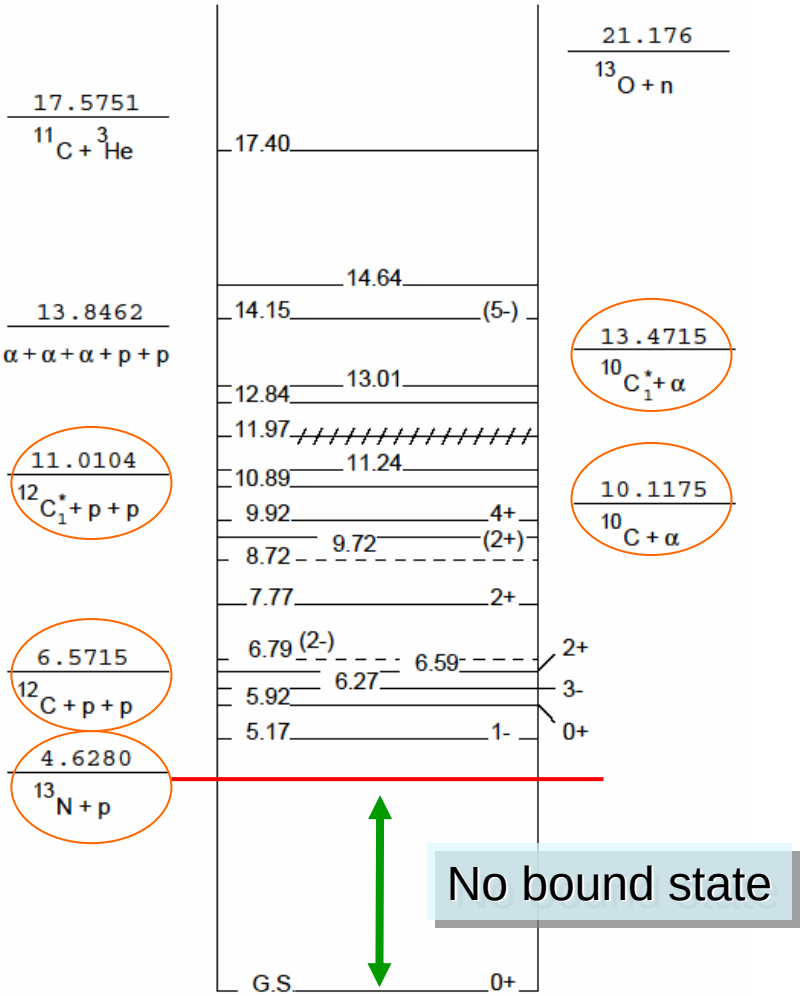
- Beam line
  - Plastic x2, PPAC x2
- For charged particle
  - ΔE-E1-E2 Plastic scintillator Hodoscope
  - 1m x 1m
  - In vacuum
- For γ ray
  - NaI scintillator x 68

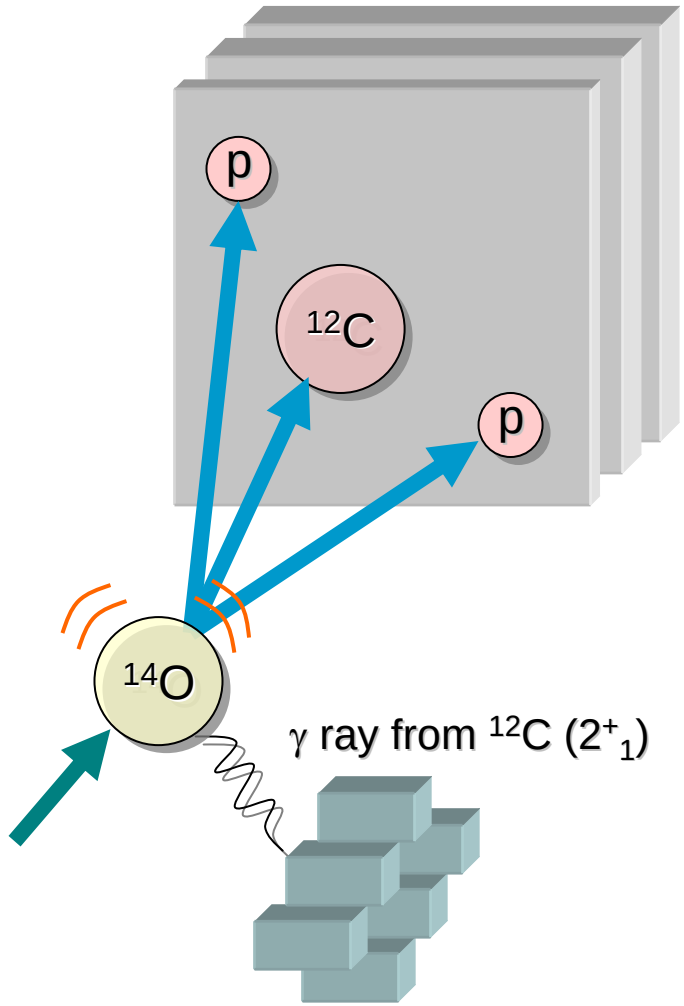


Decay channels

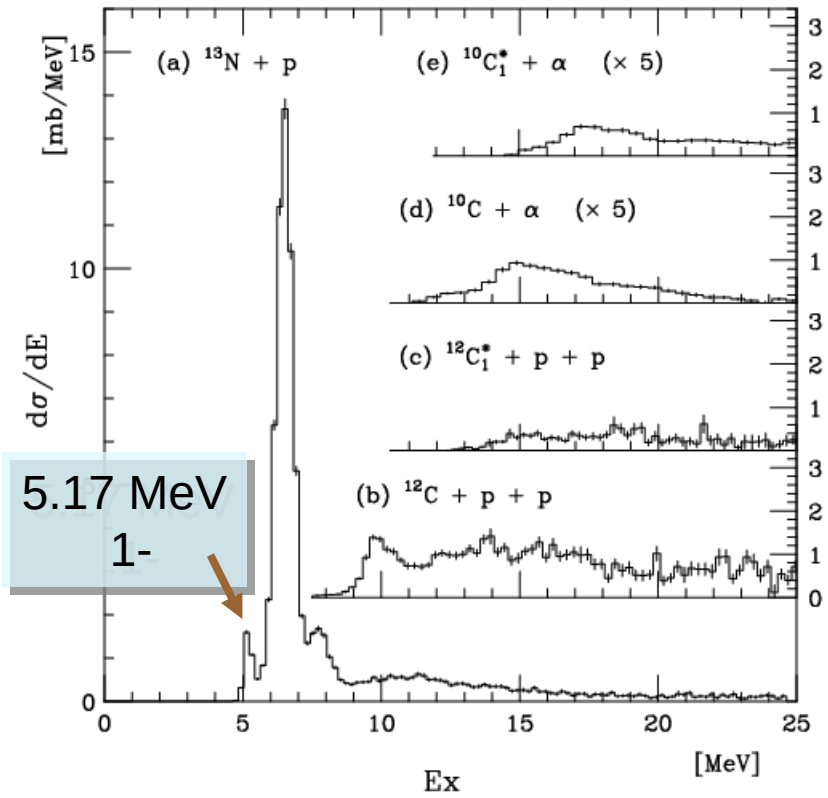
$$E_{decay} = \sqrt{\left\{\sum_i (m_i + T_i)\right\}^2 - \left\{\sum_i \mathbf{p}_i\right\}^2} - \sum_i m_i$$

$$E_x = E_{threshold} + E_{decay} + E_\gamma$$



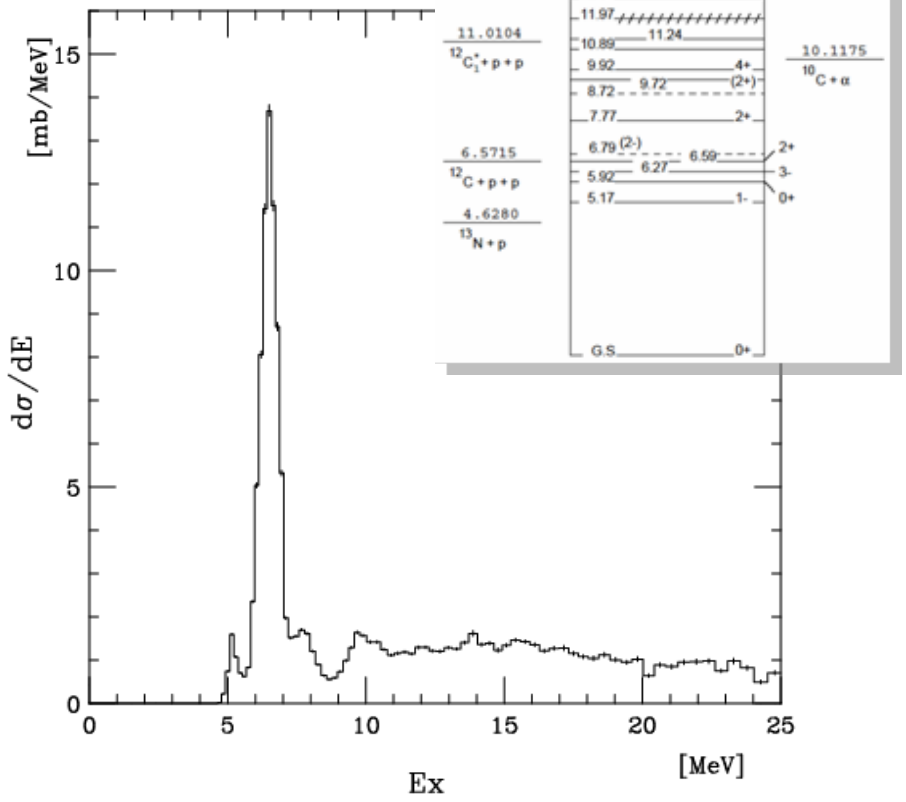


Excitation energy spectra



5.17 MeV
1-

Sum



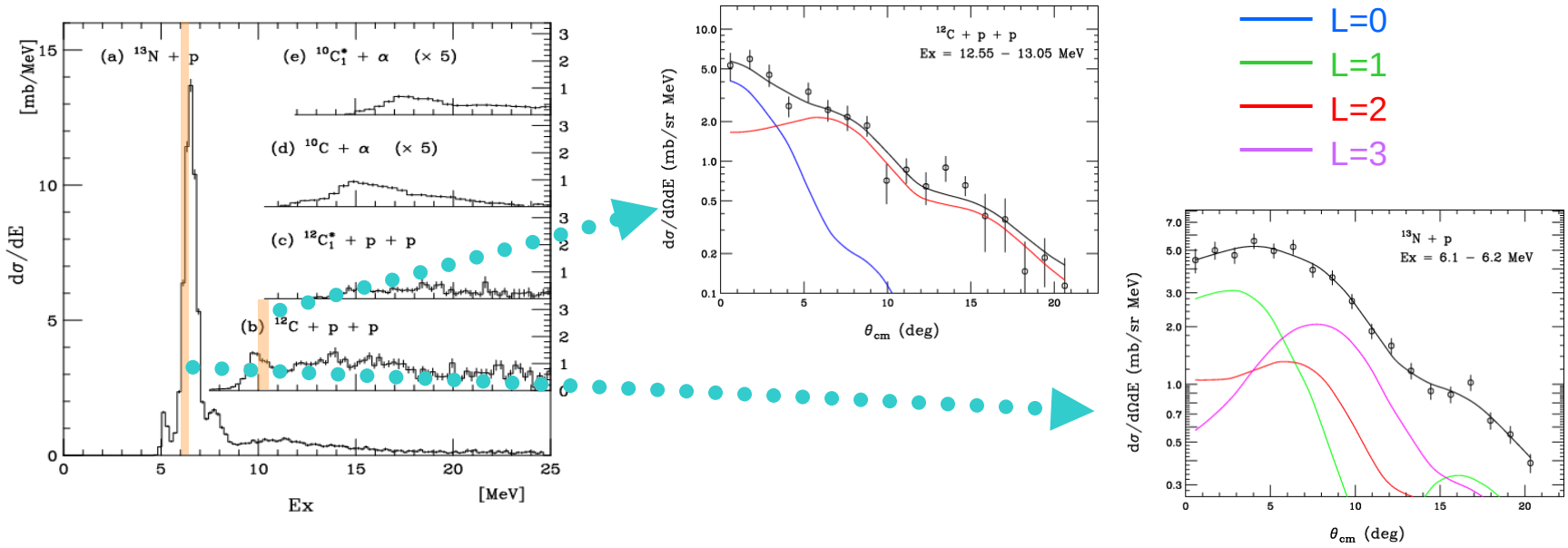
Extract multipole strength

- Multipole decomposition analysis
  - $$\left(\frac{d^2\sigma}{d\Omega dE}\right)^{EXP} = \sum_L a_L(E)\left(\frac{d^2\sigma}{d\Omega dE}\right)^{DWBA}$$

Multipole components
DWBA caluclration
100% EWSR

Experimentally obtained cross sections

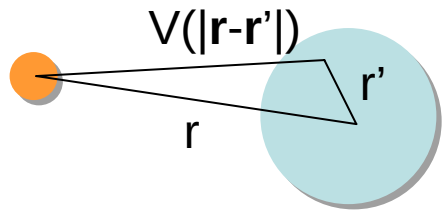
EWSR fraction (strength) to be obtained



DWBA for isoscalar excitations

- Single-folding model
  - With density dependence
  - "Renormalized" ground state density
    - $\widetilde{\rho_0}(r') = \left(1 + \beta \rho_0(r')^{2/3}\right) \rho_0(r')$

Density dependence



  - Optical potential
    - $U(r) = \int d\boldsymbol{r}' \widetilde{\rho_0}(r') V(|\boldsymbol{r} - \boldsymbol{r}'|)$

Nucleon-α interaction

  - Transition potential
    - $\delta U_L(r, E) = \int d\boldsymbol{r}' \delta\widetilde{\rho_L}(\boldsymbol{r}', E) V(|\boldsymbol{r} - \boldsymbol{r}'|)$

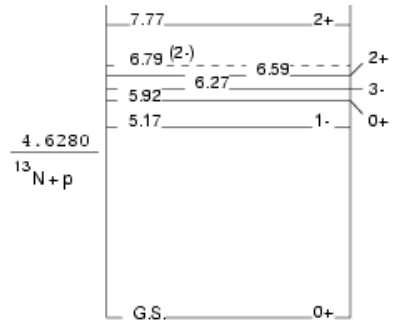
Transition density

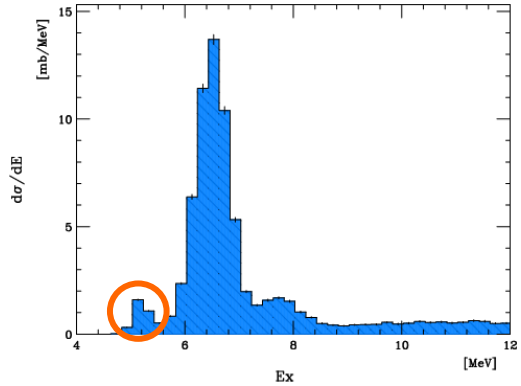
$$\delta\widetilde{\rho_{L=0}}(r', E) = -\alpha_0 \left(3 + r' \frac{r'}{dr'}\right) \widetilde{\rho_0}(r')$$

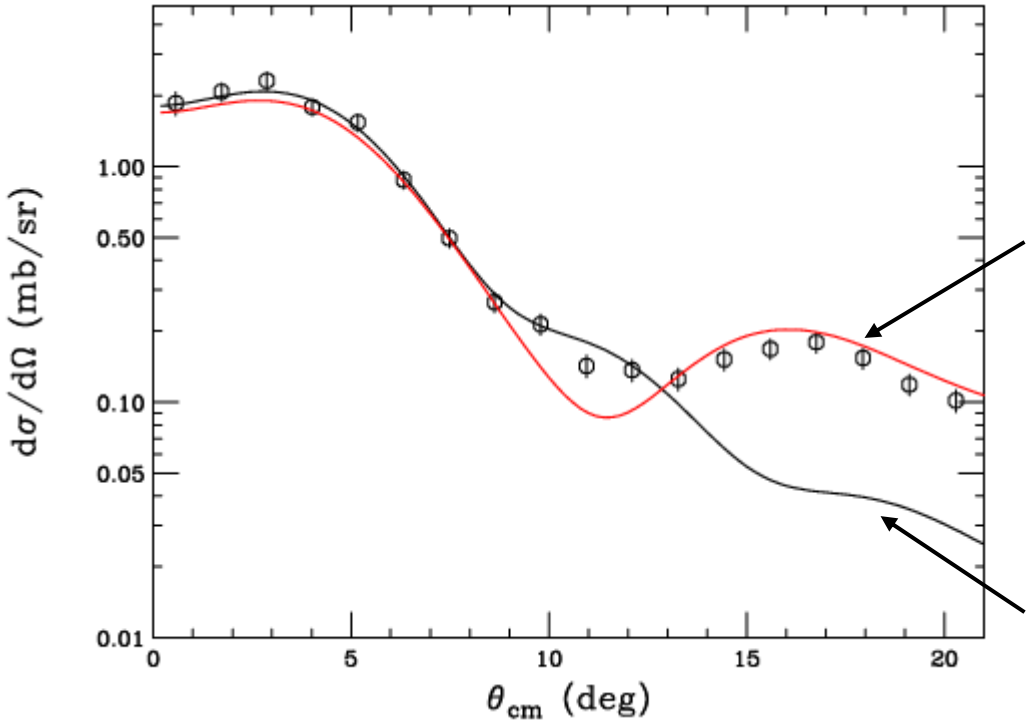
$$\delta\widetilde{\rho_{L=1}}(r', E) = -\frac{\alpha_1(E)}{R} \left[3r'^2 \frac{d}{dr'} + 10r' - \frac{5}{3}\langle r'^2 \rangle \frac{d}{dr'} + \epsilon \left(r' \frac{d^2}{dr'^2} + 4\frac{d}{dr'}\right)\right] \widetilde{\rho_0}(r')$$

$$\delta\widetilde{\rho_{L\geq 2}}(r', E) = -\alpha_L(E) r'^{L-1} \frac{d}{dr'} \widetilde{\rho_0}(r')$$

5.17 MeV 1^-







THIS WORK

With "Renormalized" ground state density

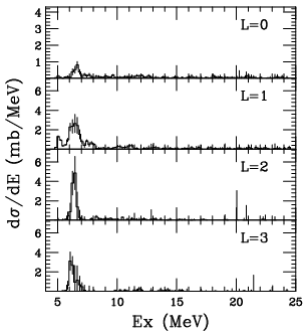
$$\widetilde{\rho_0}(r') = \left(1 + \beta\rho_0(r')^{2/3}\right)\rho_0(r')$$

With density-dependent nucleon-α interaction

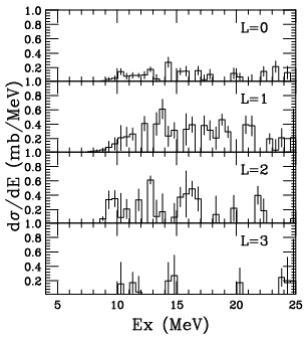
$$V_{DD}(|\boldsymbol{r} - \boldsymbol{r}'|) = V(|\boldsymbol{r} - \boldsymbol{r}'|)\left(1 + \beta\rho_0^{2/3}(r')\right)$$

Decomposed cross section

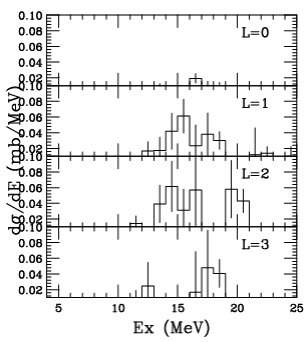
^{13}N+p



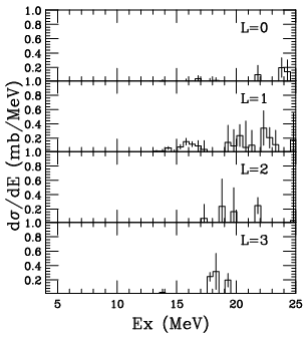
^{12}C+p+p



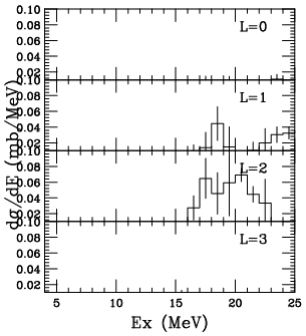
^{10}C+ α



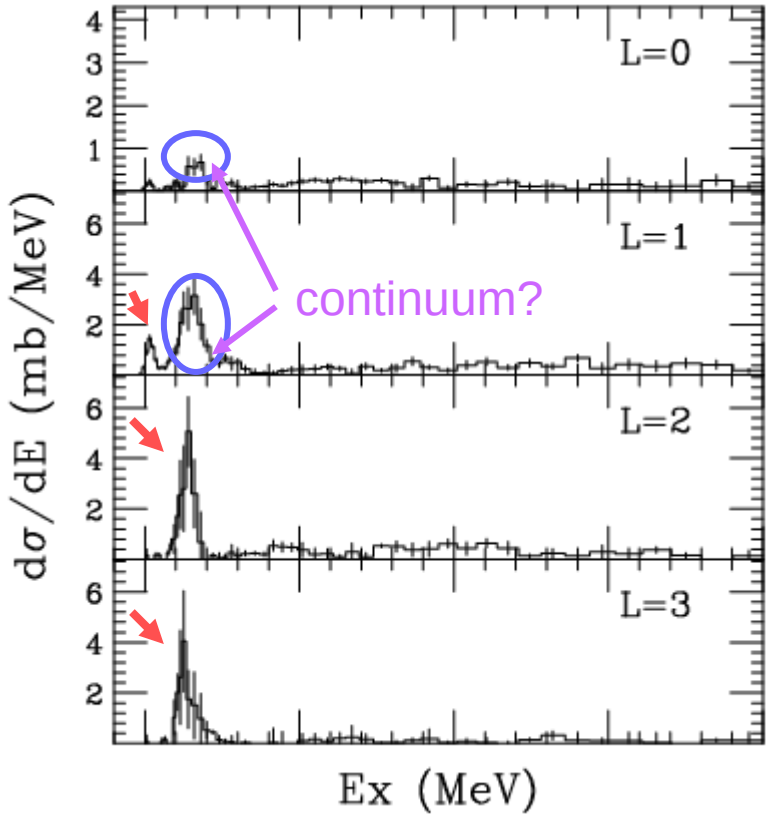
^{12}C(2^+_1)+p+p



^{10}C(2^+_1)+α



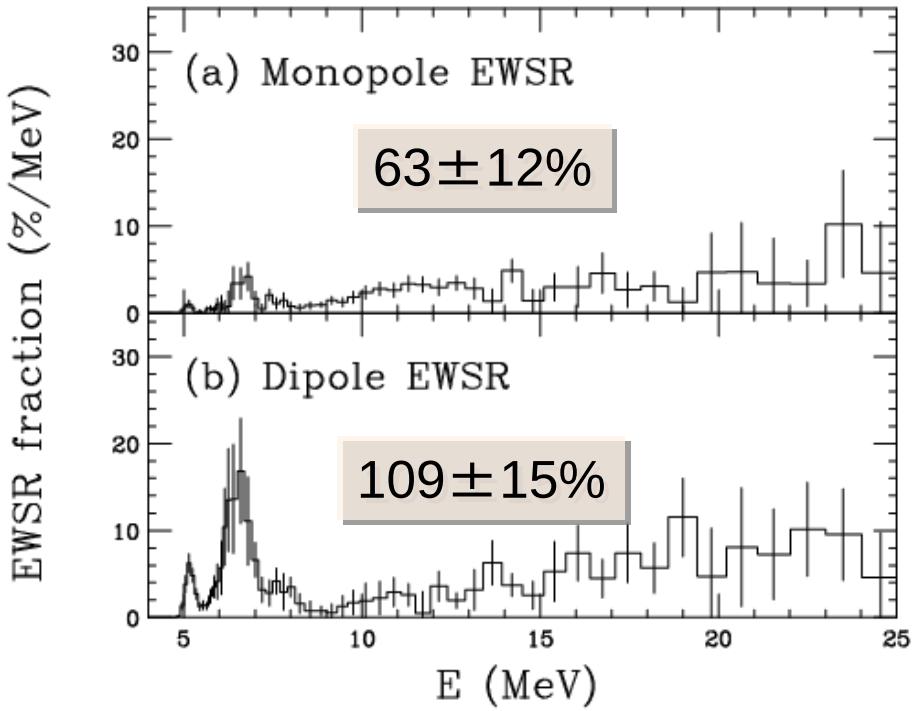
Total



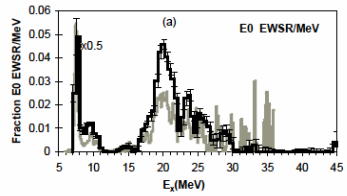
EWSR fraction for compressional modes

- Fragmented distribution
  - Common with stable nuclei

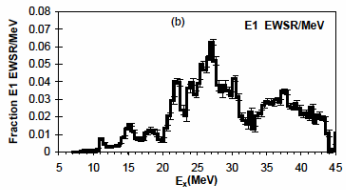
^{14}O (0-25MeV)



^{12}C (0-45 MeV)

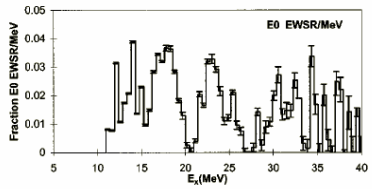


41±6%

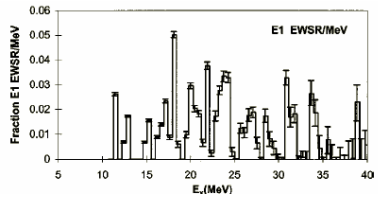


78±9%

^{16}O (11-40 MeV)



48±10%



32±7%

• B. John et. al., Phys. Rev. **C68** (2003) 014305
• Y.-W. Lui et. al., Phys. Rev. **C64** (2001) 064308

Summary

- Inelastic α scattering on ^{14}O was measured
  - Excitation energy spectra was obtained
  - Some decay channels were not analyzed
- DWBA with density dependence was studied
  - “Renormalized” ground state density was proposed
- Isoscalar multipole strengths were deduced
  - Fragmented distributions

- Next = inelastic α scattering @ RIBF
  - Compressional excitation on weekly-bound nuclei?

Collaboratos

- H. Baba, S. Shimoura, T. Minemura
- Y. U. Matsuyama, A. Saito, H. Ryuto, N. Aoi
- T. Gomi, Y. Higurashi, K. Ieki, N. Imai, N. Iwasa
- H. Iwasaki, S. Kanno, S. Kubono, M. Kunibu
- S. Michimasa, T. Motobayashi, T. Nakamura
- H. Sakurai, M. Serata, E. Takeshita, S. Takeuchi
- T. Teranishi, K. Ue, K. Yamada, Y. Yanagisawa