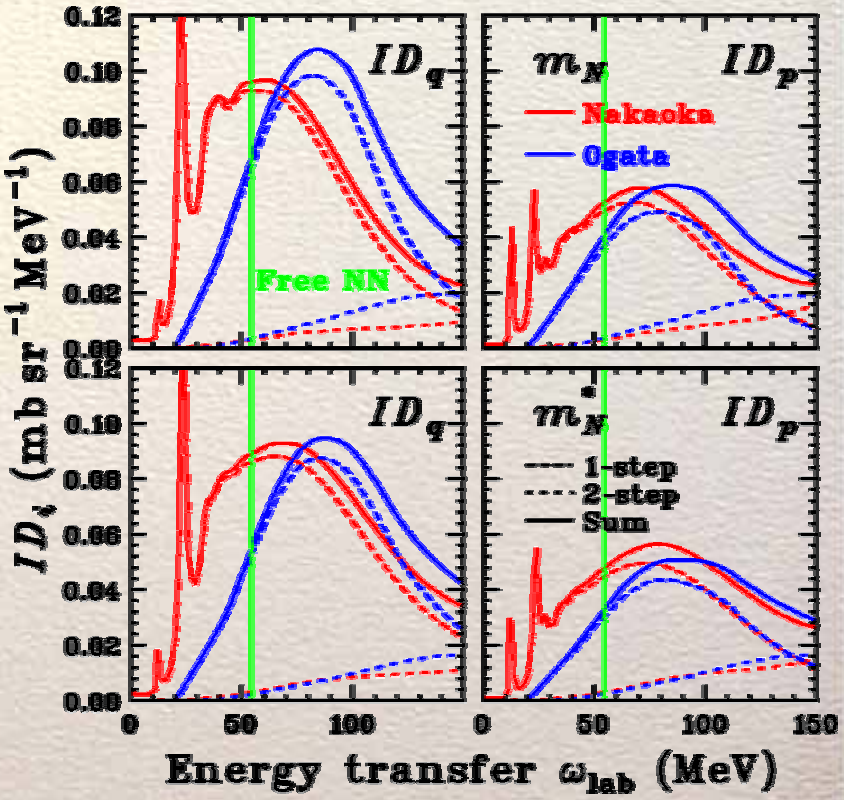
Comparison between theoretical calculations for QES processes

- Nakaoka et al.
  - PWA for 2-step; DWIA+free for 1-step
  - Franey and Love t-matrix
  - Free-mass case: On-shell approx.
  - m* case: w/o on-shell approx.
- Ogata et al.
  - SCDW model
  - Melbourne free t-matrix
  - Free-mass and m* cases
- Results
  - Free-mass: m
    - 1-step: Nakaoka Ogata
    - 2-step: Nakaoka < Ogata
  - Effective mass: m*
    - 1- and 2-steps: Nakaoka Ogata
  - Peak shift from free NN
    - Nakaoka: little shift (*energy dependence of distortion effects*)
    - Ogata: large shift



Peak shift mechanism and binding-energy effect for QES

- Energy transfer ω for QES at q

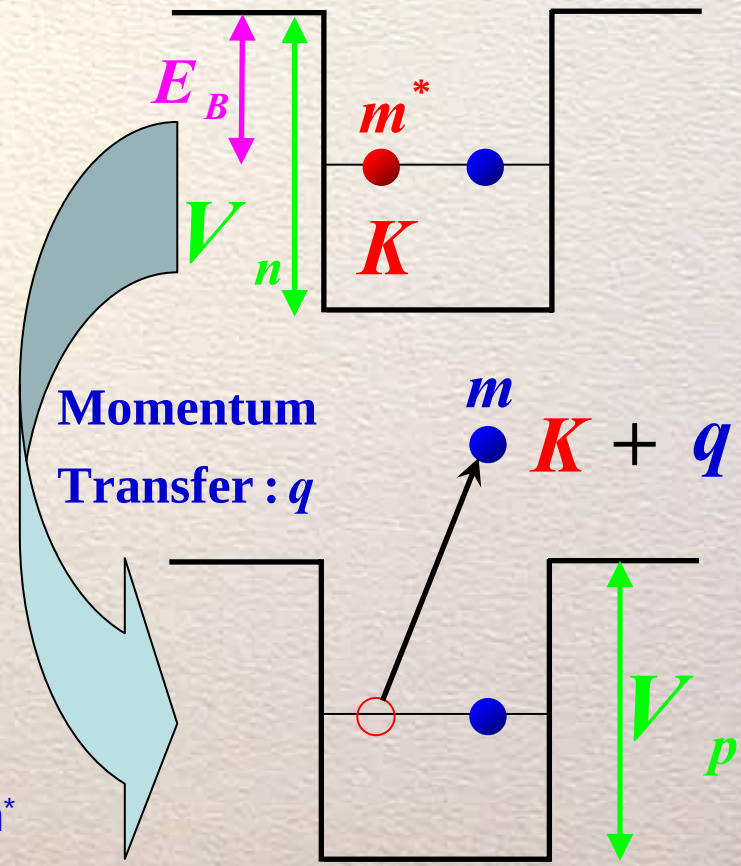
$$\omega = \left[\frac{(K+q)^2}{2m} + V_p\right] - \left[\frac{K^2}{2m} + V_n\right]$$

$$= \frac{q^2}{2m} + \frac{K \cdot q}{m}$$

NN Peak — Width — Peak Shift

$$+ \frac{K^2}{2}\left(\frac{1}{m} - \frac{1}{m^*}\right) + (V_p - V_n)$$

  - **Binding energy E_B does not contribute to the peak shift**
  - Peak shift depends on single particle potentials V and the effective mass m^*
  - (p,n):Shift = 20-30 MeV
  - (p,p'):Shift = 0-10 MeV



Peak shift mechanism and Q-value effect for QES

- ^{12}C(p,n) case

Single particle	Energy (B.E.)	Potential
Neutron in ^{12}C	B_n=-18.72 MeV	V_n=-72.76 MeV
Proton in ^{12}N	B_p= -0.60 MeV	V_p=-49.92 MeV

  - $Q = B_n - B_p = -18.1\text{MeV} \approx \Delta V = V_n - V_p = -22.8\text{MeV}$
  - $\text{Shell Gap} << Q \approx \Delta V \approx \Delta\omega$

- ^{40}Ca(p,n) case

Single particle	Energy (B.E.)	Potential
Neutron in ^{40}Ca	B_n=-15.64 MeV	V_n=-64.42 MeV
Proton in ^{40}Sc	B_p= -0.54 MeV	V_p=-60.63 MeV

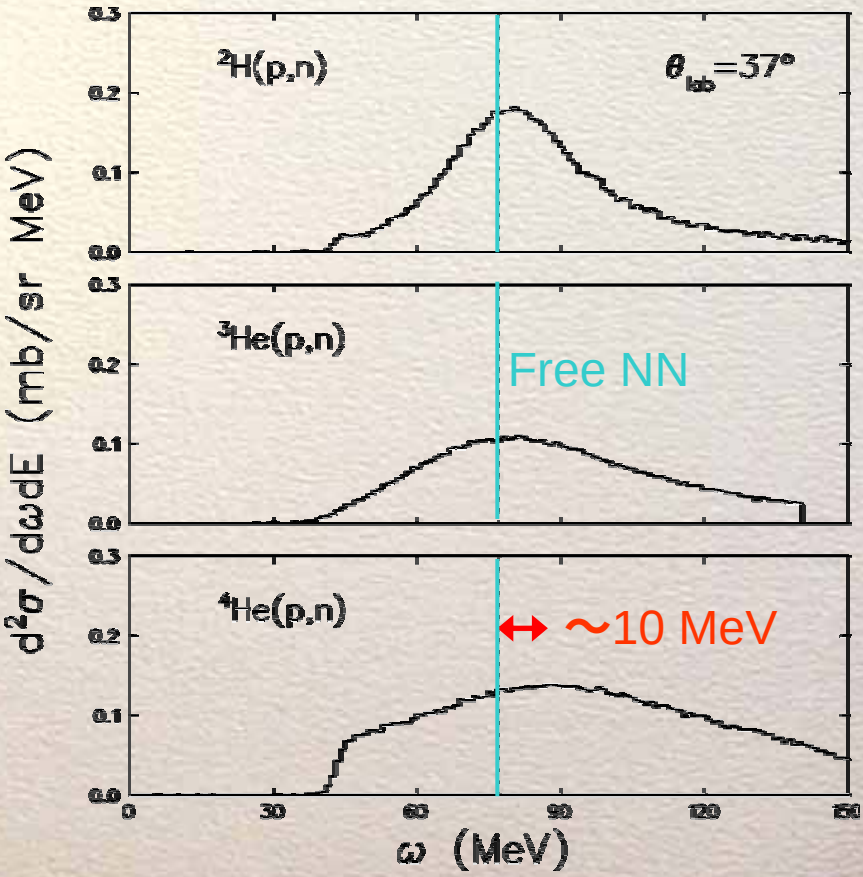
  - $Q = B_n - B_p = -15.1\text{MeV} << \Delta V = V_n - V_p = -3.8\text{MeV}$
  - $\text{Shell Gap} \approx Q \approx \Delta\omega << \Delta V$

- QES peak shift: $\Delta\omega \sim$20 MeV for ^{12}C(p,n) and ^{40}Ca(p,n)
  - $\Delta\omega$ should depend on ΔV
  - $\Delta V \not\leftrightarrow Q \Rightarrow \Delta\omega \not\leftrightarrow Q$

QES peak should not (directly) depend on Q-value

QES peak shift for light nuclei

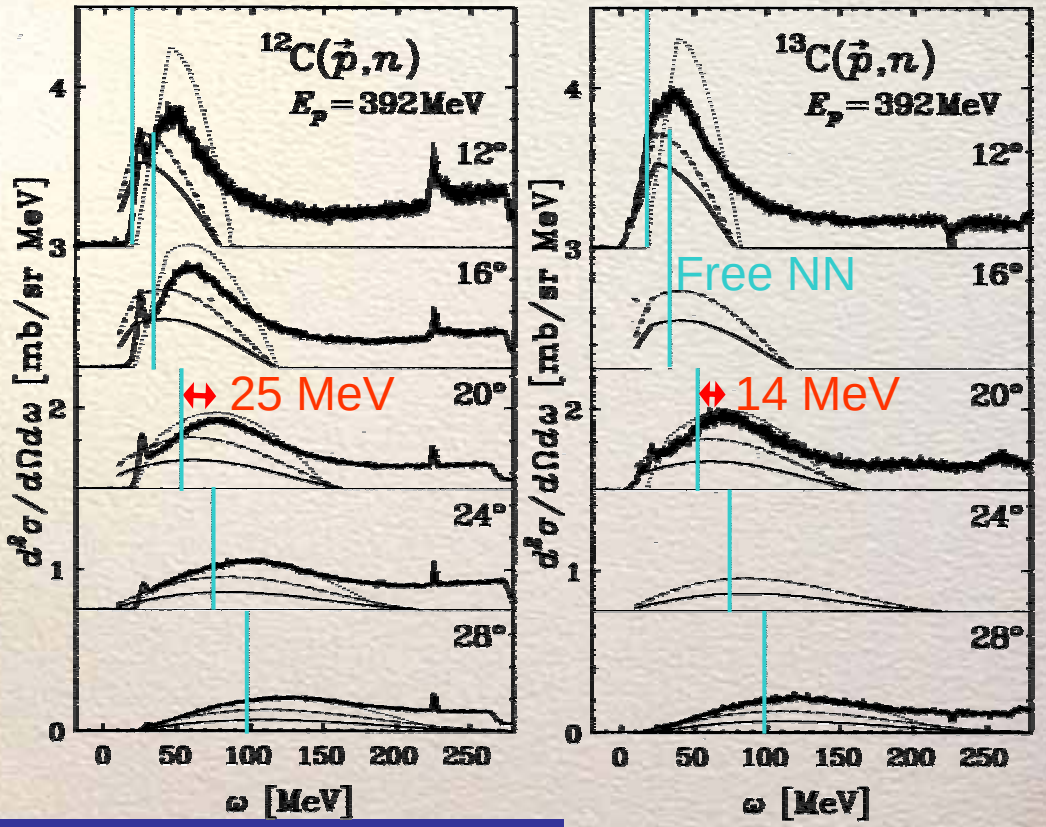
- ^{2}H, ^{3}He(p,n)
  - Q-values
    - ^{2}H: -2.2 MeV (Break-up)
    - ^{3}He: -1.8 MeV
  - Almost no shift
  - m* and ΔV effects: ✕
- ^{4}He(p,n)
  - Q-value: -23.7 MeV
  - Peak shift: ~10 MeV < Q-value
  - m* and ΔV effects ?



D.L Prout et al., Phys. Rev. C 65, 034611 (2002)

QES peak shift for C isotopes

- ^{12}C, ^{13}C(p,n)
  - m* and distortion effects would be same
  - Q-values
    - ^{12}C: -18.1 MeV
    - ^{13}C: -3.0 MeV
  - Single particle potential
    - ^{12}C: ΔV=22.8 MeV
    - ^{13}C: ΔV= 0.5 MeV
  - Peak shift
    - ^{12}C: $\Delta\omega$=25±3 MeV
    - ^{13}C: $\Delta\omega$=14±7 MeV
- Results
  - Peak-shift difference ～ Q-value difference
  - Peak-shift difference < ΔV difference
  - ΔV difference for C isotopes is physically appropriate?



H. Otsu,
Doctoral Dissertation
Univ. of Tokyo (1997)

Distortion, m*, and correlation effects for QES peak shift

- PWIA/DWIA calculations
  - PW vs. DW
  - m (free mass) vs. m* (effective mass)
  - Free response (0^{th}) vs. RPA response
- Contribution to peak shift
  - PW+m+Free response(0^{th}) =Free NN
  - Distortion: +8 MeV
  - m*(effective mass): +6 MeV
  - RPA (correlation): +6 MeV
  - Total: +20 MeV