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Spin-isospin Correlation in Light Neutron Rich Nuclei

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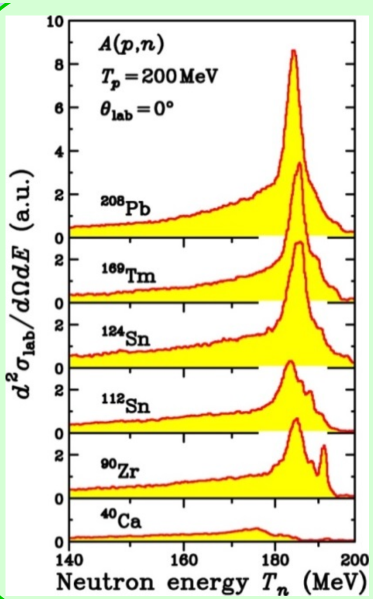
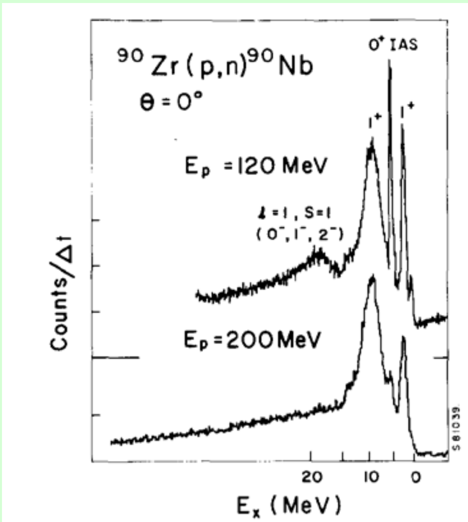
Spin-isospin physics: Gamow-Teller responses

Last century

- $\sigma\tau_{\pm}$ induces GT transition
- 1963 GT giant resonance predicted, Ikeda sum rule 3(N-Z)
  collectivity?
- ~1980 GT giant resonances established
- Strength quenched/missing: 50-60% of 3(N-Z) due to Δh or 2p2h ?
- 1997 ~90% of 3(N-Z) found
- Charge-exchange (p,n)/(n,p) reactions on stable target nuclei

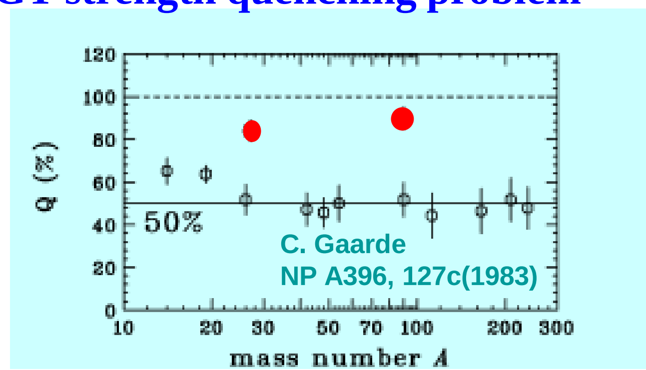
- C. Garrde, NPA396(1982)127c.





- Wakasa et al., PR C55, 2909 (1997)

GT strength quenching problem



- **Wakasa et al.,** PR C **55**, 2909 (1997)

Gamow-Teller responses in isospin extreme

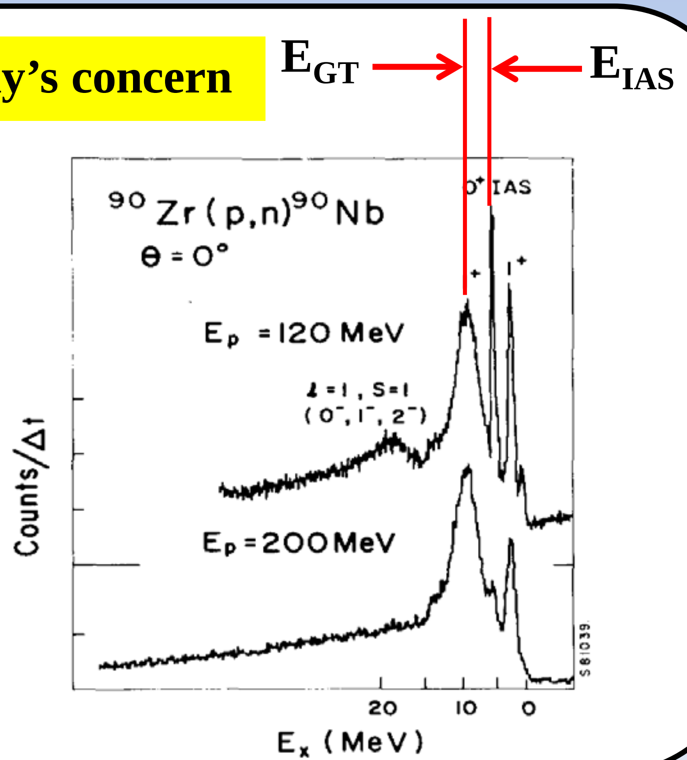
This century

- **Unstable** beams → extend the horizon of spin-isospin responses

Today's subject

- Gamow-Teller Giant Resonance(GTGR) under isospin extreme condition
  → Large (N-Z)/A asymmetry
  → GTGR in ery neutron rich light nuclei

Today's concern



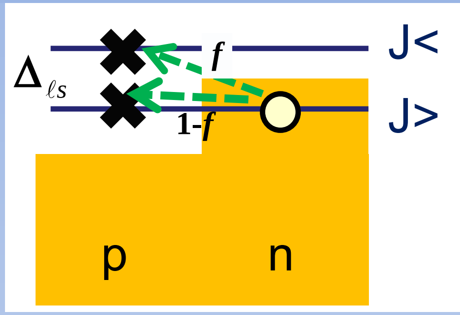
E_{GT} - E_{IAS}

Peak energy represents the spin-isospin correlations.

Spin-isospin correlations in schematic model

- **GTGR (IAS) induced by *ph* residual interaction:**

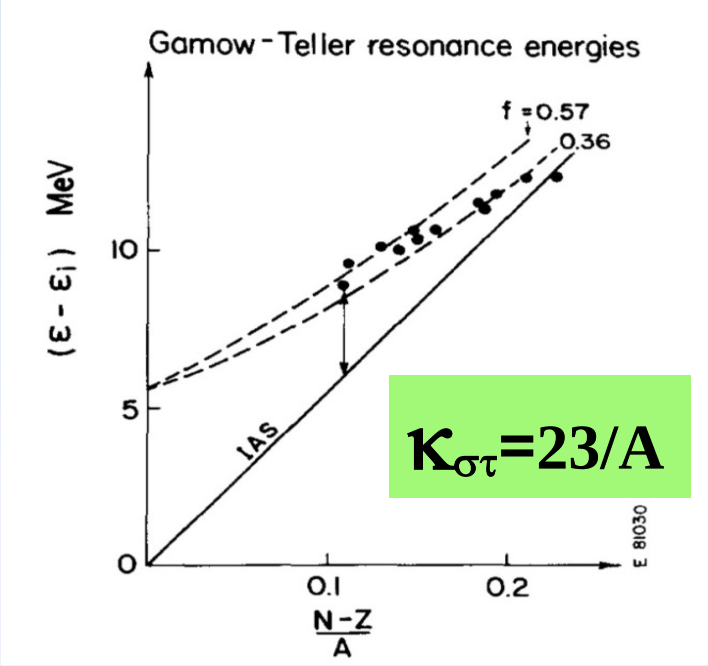
$$V_{12} = \kappa_{\sigma\tau}\vec{\sigma}_1\vec{\sigma}_2\vec{\tau}_1\vec{\tau}_2 \quad (\kappa_\tau\vec{\tau}_1\vec{\tau}_2)$$



- **Dispersion relation for the collective state(GTGR)**

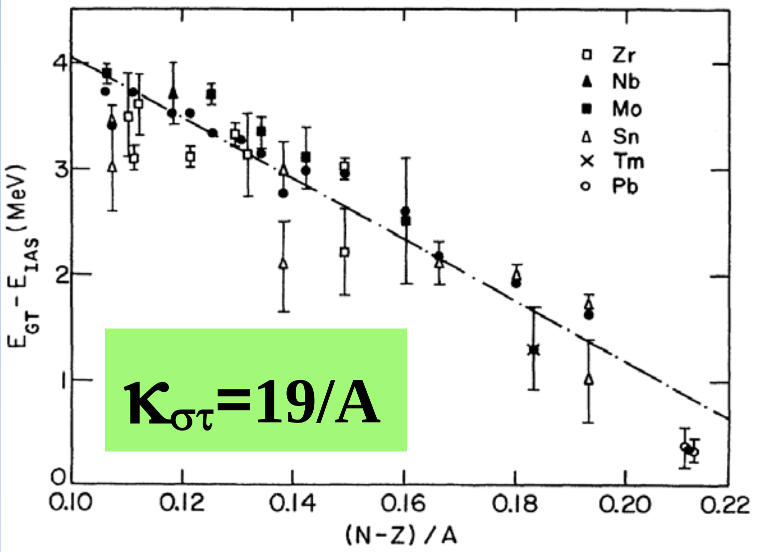
$$\frac{2(N-Z)(1-f)}{\varepsilon_i - \varepsilon} + \frac{2(N-Z)f}{\varepsilon_i + \Delta_{\ell s} - \varepsilon} = -\frac{1}{\kappa_{\sigma\tau}}$$

- **C. Garrde, NPA396(1982)127c.**



$\kappa_{\sigma\tau}$=23/A

- **Nakayama et al.,PLB114(1982)217**

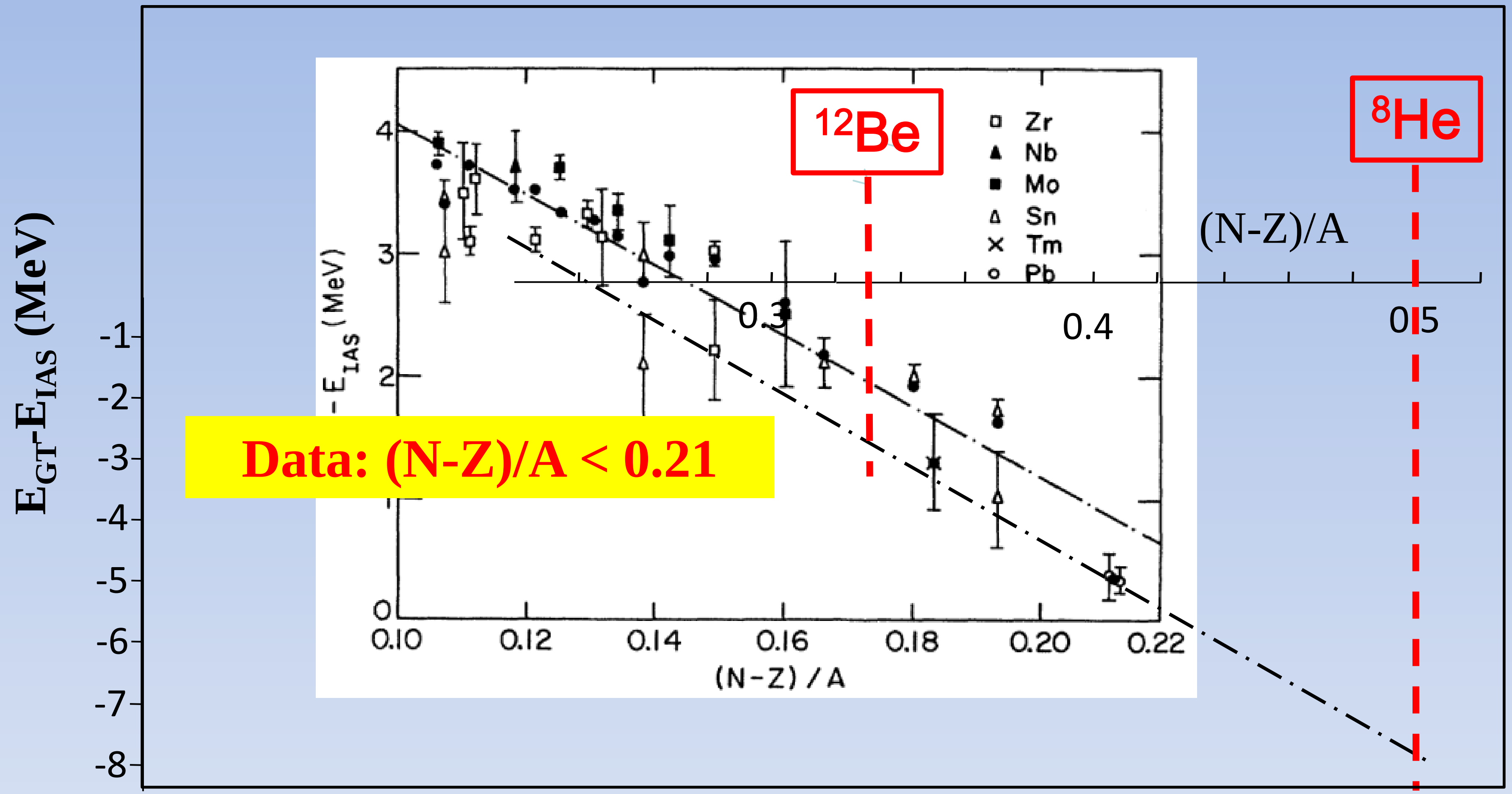


$\kappa_{\sigma\tau}$=19/A

$$E_{\mathrm{GT}} - E_{\mathrm{IAS}} = \Delta_{\ell s} + 2(\kappa_{\mathrm{GT}} - \kappa_{\mathrm{F}})\frac{(\mathrm{N}-\mathrm{Z})}{\mathrm{A}}$$

Collectivity in (N-Z)/A>0.21:very nuetron rich nuclei

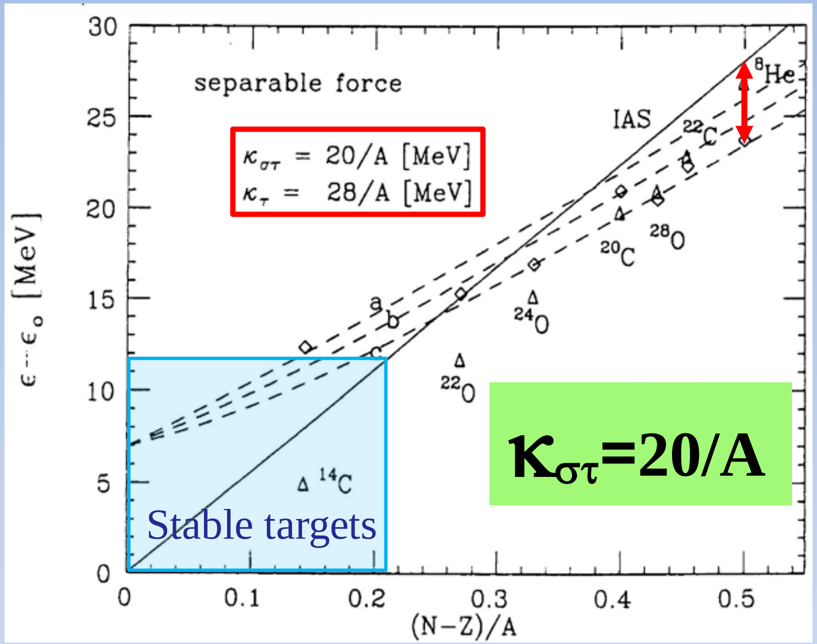
K.Nakayama et al, PLB114(1982)217.



Schematic model for (N-Z)/A>

- **Predicted in 1993 by Sagawa-Hamamoto-Ishihara(SHI), PL B303 (1993) 215.**

Hartree-Fock + RPA (TDA) calculation

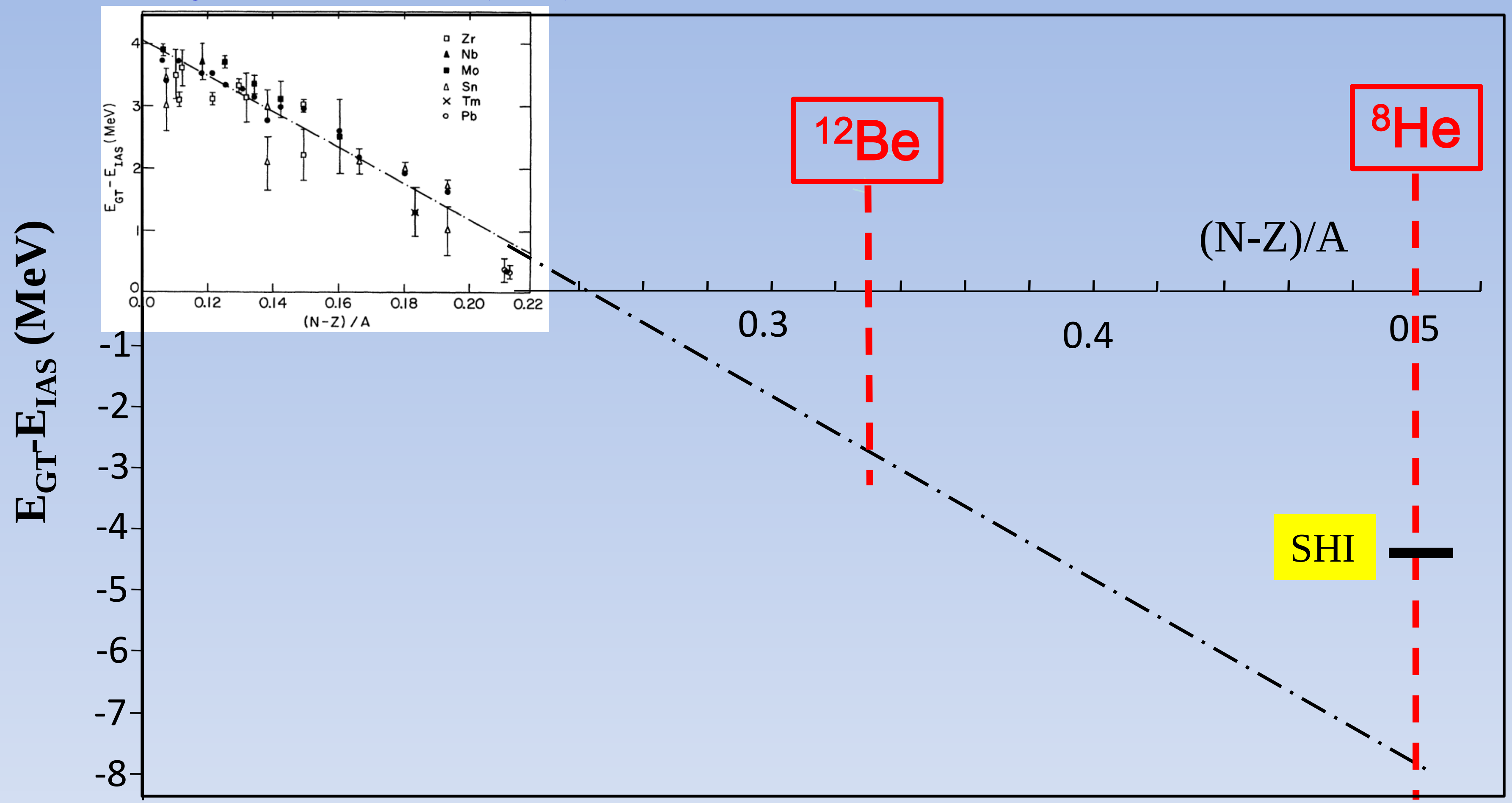


- **For large (N-Z)/A**
  → $E_{GT} - E_{IAS} < 0$

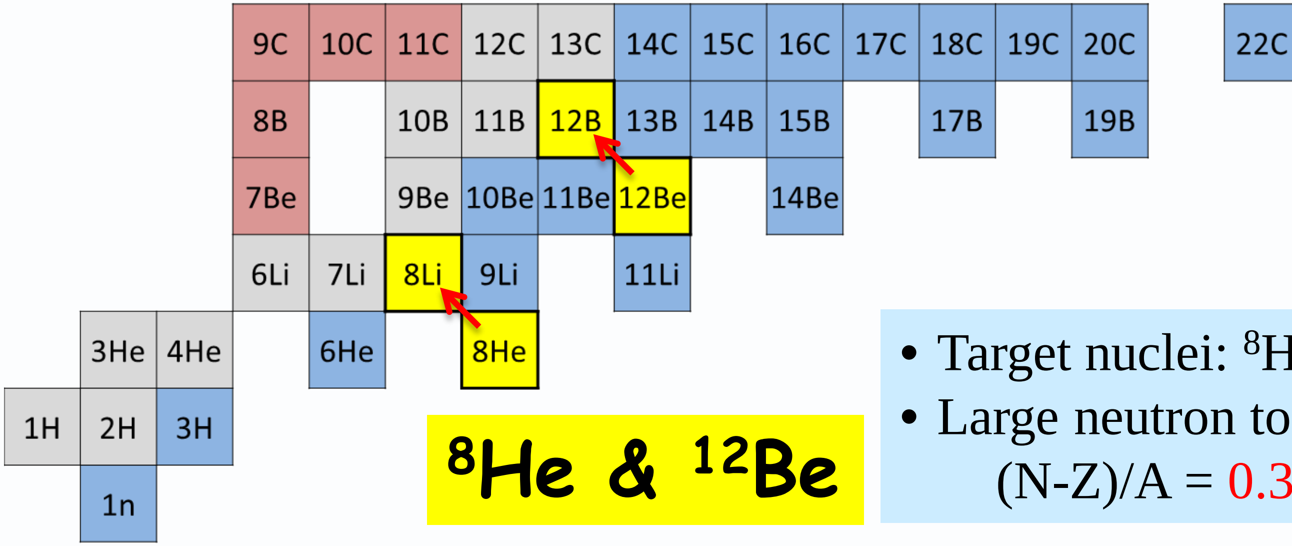
- **^{8}He : $E_{GT} - E_{IAS} = -4.3$ MeV**
  (f=0.44)

Collectivity in (N-Z)/A>0.21:very nuetron rich nuclei

K.Nakayama et al, PLB114(1982)217.



GTGR in ^{8}He & ^{12}Be



^{8}He & ^{12}Be

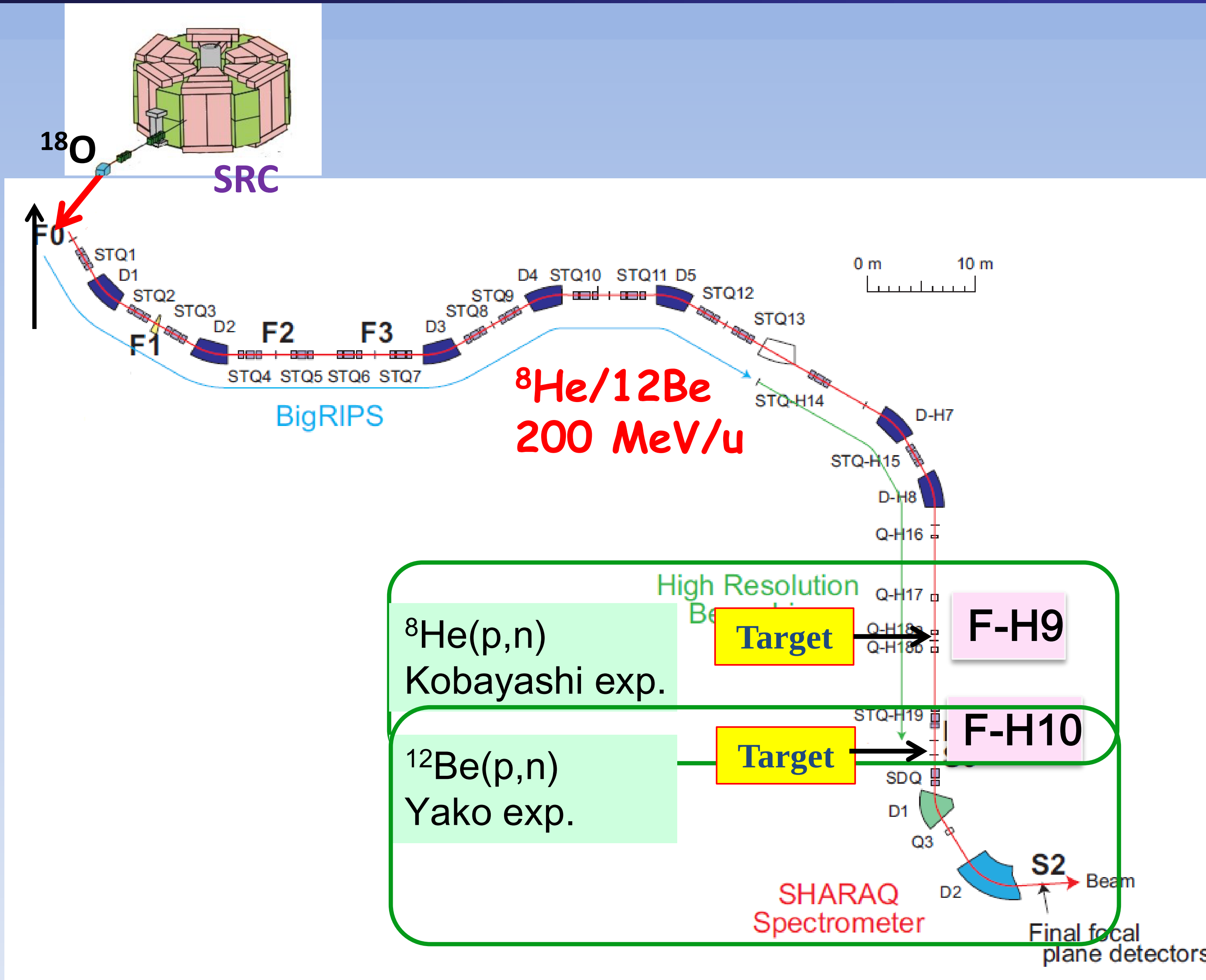
- Target nuclei: ^{8}He and ^{12}Be
- Large neutron to proton ratio
  (N-Z)/A = 0.33(^{12}Be), 0.5(^{8}He)

- ^{8}He : neutron skin (+halo) α+4n
- ^{12}Be: neutron halo
  - admixture of 2*s*-orbit into 1*p*-shell
  - large deformation (2:1)
  - cluster structure α+α+4n

Experiment

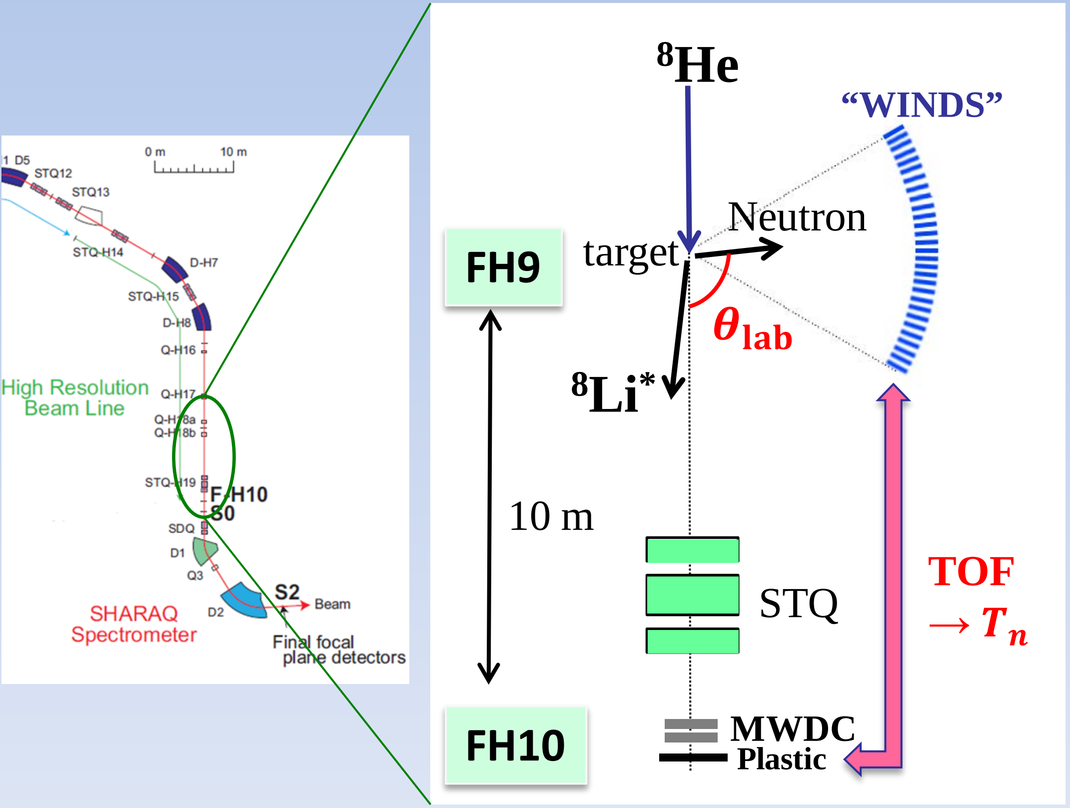
- (p,n) reaction in inverse kinematics
- ^{8}He(p,n) by Kobayashi *et al.*,
- ^{12}Be(p,n) by Yako *et al.*,

^{8}He/^{12}Be(p,n) measurements at RIBF



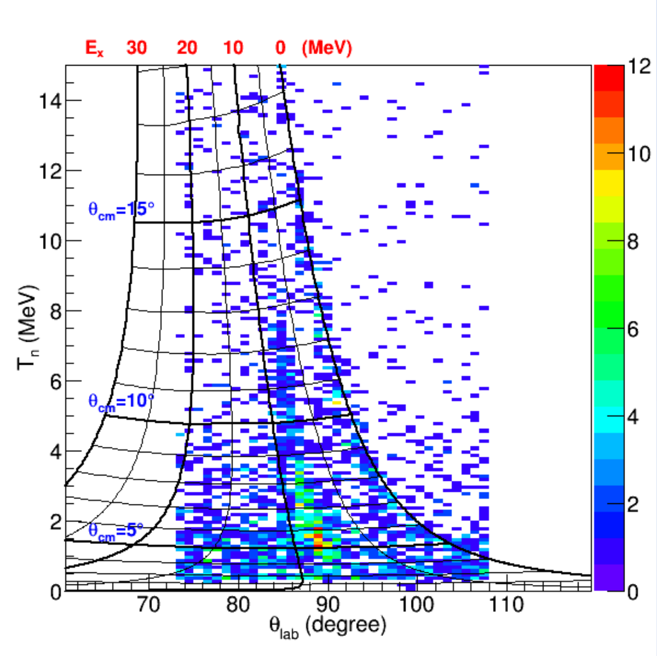
Measurement on $^{8}He(p,n)^{8}Li$ @ 200 MeV/u

- ^{8}He(200 MeV/u) beam 2 Mpps
- CH_2 and C
- Neutrons(TOF) by a half of WINDS
- Residual nucleus(^{7}Li/^{8}Li)



- Under inverse kinematics

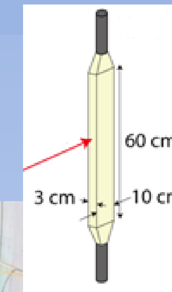
$$(T_n, \theta_{\mathrm{lab}}) \rightarrow (E_x, \theta_{\mathrm{cm}})$$



Measurement on $^{12}Be(p,n)^{12}B$ @ 200 MeV/u

- ^{12}Be(200 MeV/u) beam 0.5-1 Mpps
- Liq. Hydrogen target
- Neutrons(TOF) by WINDS
- Residual nucleus(SHARAQ)

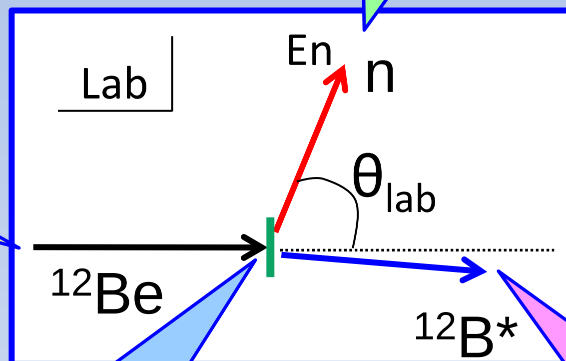
Wide-angle
Inverse-kinematics
Neutron
Detectors for
SHARAQ



- **59 plastic scintillators (BC408)**
  (H7195 + BC408, 60 x 10 x 3 cm³)
- **θ = 60-120°, FPL = 180 cm**

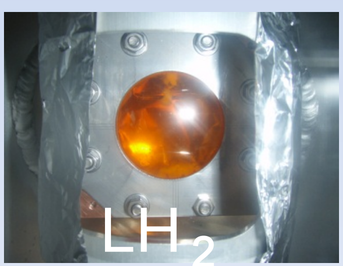
Neutron detector TOF method

^{18}O beam + Be→^{12}Be
Achromatic transport



Liquid hydrogen target

SHARAQ
^{12}B, ^{11}B, ^{10}B

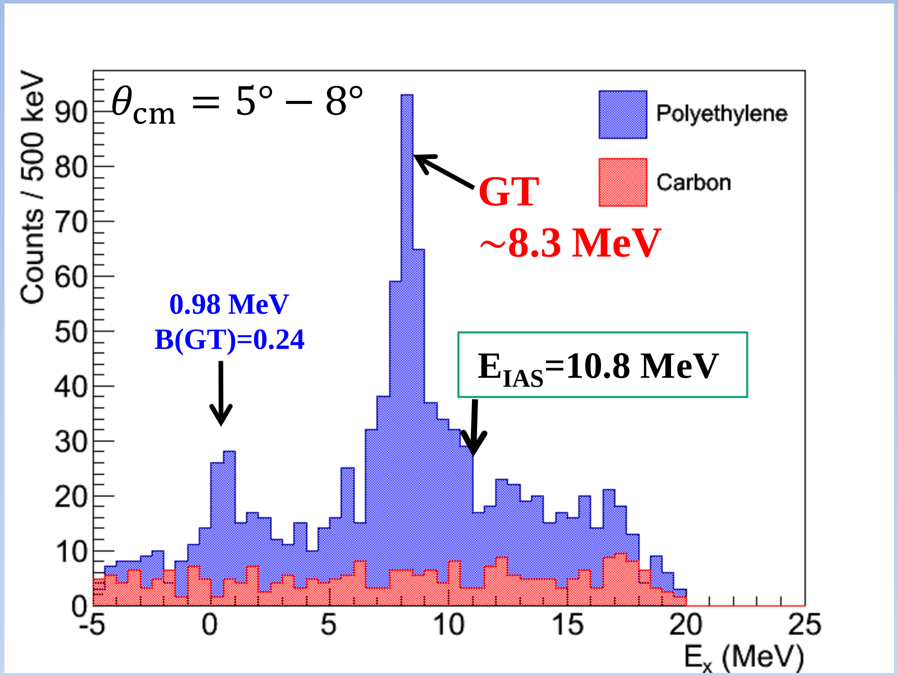


- **Liq H_2, 14 mmt**

- **Acceptances**
  |δ| < 1%
  |θ| < 36 mr, |Φ| < 68 mr

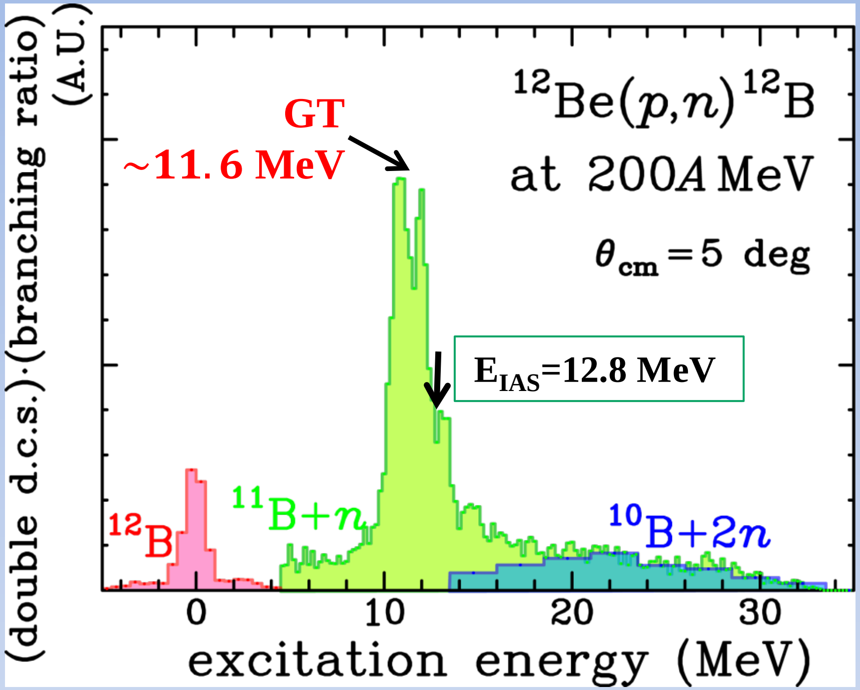
Results

- ^{8}He(p,n) at 200 MeV/u



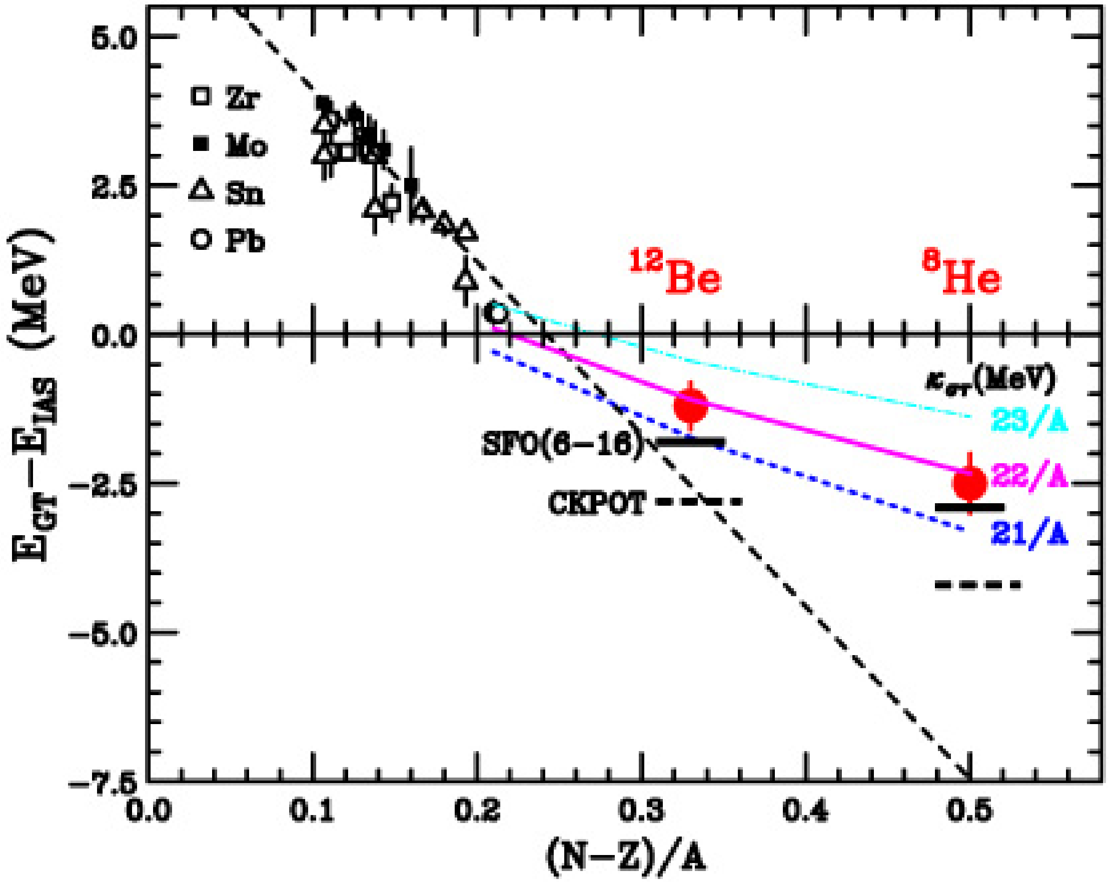
$E_{GT} - E_{IAS} = -2.5 \pm 0.5$ MeV

- ^{12}Be(p,n) at 200 MeV/u



$E_{GT} - E_{IAS} = -1.2 \pm 0.4$ MeV

Comparison to model predictions



- Significantly deviate from empirical line.
- $\kappa_{\sigma\tau}$=22/A : good job
- CK (8-16)POT : poor job
- New SFO(6-16) : better

$\kappa_{\sigma\tau}$=28/A fixed

Comparison of $\kappa_{\sigma\tau}$

	Present result ^{8}He and ^{12}Be	SHI (PL B303 (1993) 215) HF+TDA	Gaarde (NP A 396 (1983)127c) ^{208}Pb	Nakayama (PL 114B (1982) 217) ^{90}Zr - ^{208}Pb
$A\kappa_{\sigma\tau}$ (MeV)	22	20	23	19
$A\kappa_{\tau}$ (MeV)	28	28	28	28

(N-Z)/A > 0.22 (Present result, SHI)

< 0.22 (Gaarde, Nakayama)

Summary

- GTGRs measured for ^{8}He ((N-Z)/A =0.5) and ^{12}Be (=0.33) by SHARQ Collaboration

- ΔE=E(GT)-E(IAS) deduced
  - ΔE=–2.5 MeV(^{8}He)/–1.2MeV (^{12}Be)   (ΔE> 0 for stable nuclei)
  - Nakayama empirical line: –7.5 MeV(^{8}He)/–2.5 MeV (^{12}Be)

- Compared to schematic model and to shell model
  - $\kappa_{\sigma\tau}$~22/A MeV (κ_{τ}~28/A MeV)
    - 20/A MeV by SHI of 1993 (HF+TDA)
    - 23/A MeV for ^{208}Pb by Gaarde
  - CK(8-16)POT: poor description
  - SFO(6-16) constructed: reasonable description

- Highly interesting to measure GTGR/IAS of
  - ^{14}Be ((N-Z)/A=0.43), ^{22}C ((N-Z)/A=0.46), ^{24}O ((N-Z)/A=0.33) etc.