Reconciling Giant Resonance Data

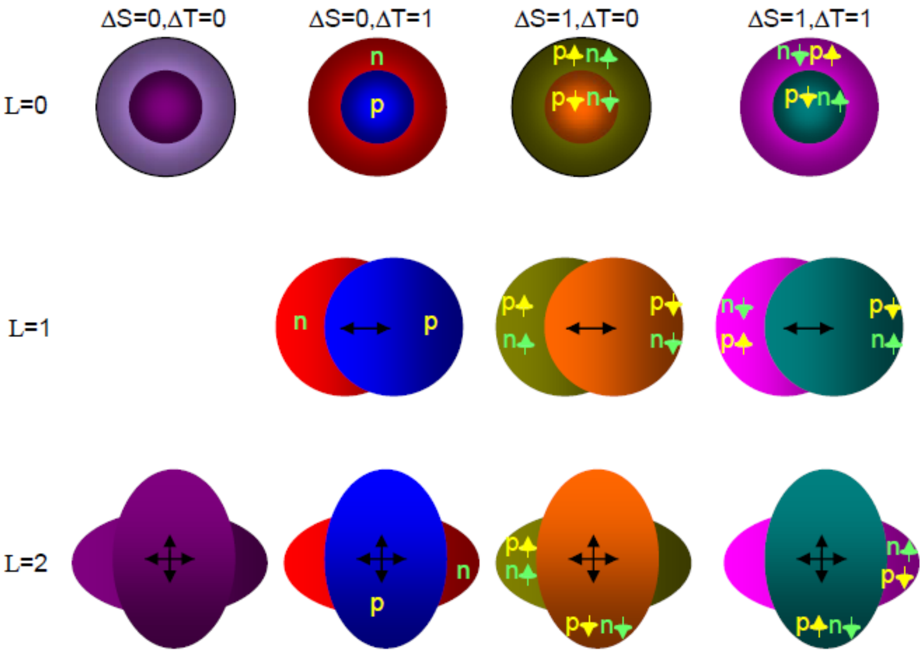
Ashton Short
Mentor: Dr. Dave Youngblood

Motivation

- Giant Resonances are important because they tell us about bulk properties of the nucleus, such as its compression modulus.
- While Gaussian fits are most common in the study of Giant Resonances, the group from Osaka University in Japan use either Lorentzian or Breit-Wigner fits. This presents a challenge when it comes to comparing results.
- The Osaka group primarily publishes radiative strength distributions rather than energy-weighted-sum-rule (EWSR) strength distributions, which also creates complications for comparing data.
- The aim of this project was to gather data from Osaka publications, convert to EWSR distributions and carry out Gaussian fits.

What are Giant Resonances?

- Giant Resonances are the collective motion of the nucleons within the nucleus.
- Resonance typically occurs at excitation energies between 10-30 MeV.
- Resonances can be isoscalar (i.e. the nucleons move in phase) or isovector (i.e. the nucleons move out of phase).
- The nucleus can take on monopole (L=0), dipole (L=1), quadrupole (L=2), etc., structures.

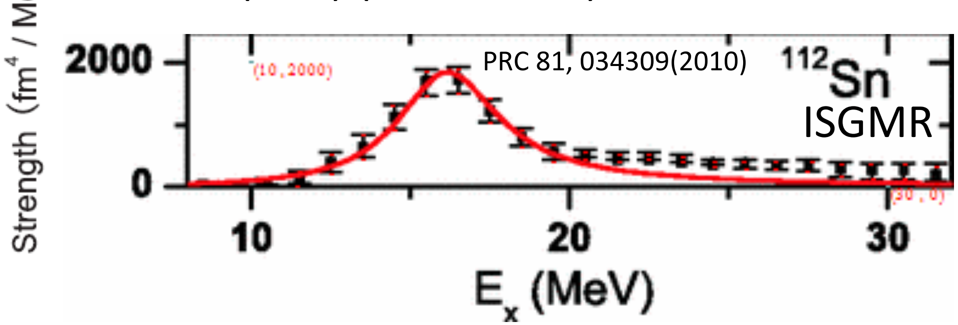


Originally from [1].

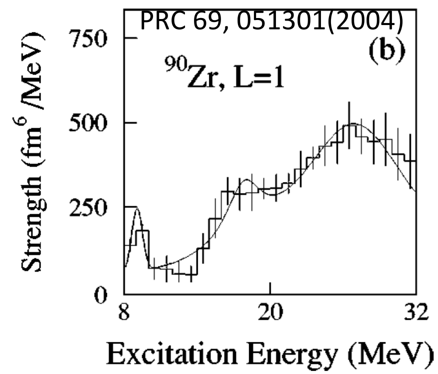
[1] S. S. Hanna, in *Proceedings of the Giant Multipole Resonance Topical Conference, edited by F. E. Bertrand (Harwood Academic publisher, Oak Ridge,* Tennessee, 1979).

Osaka Data and Some Fits

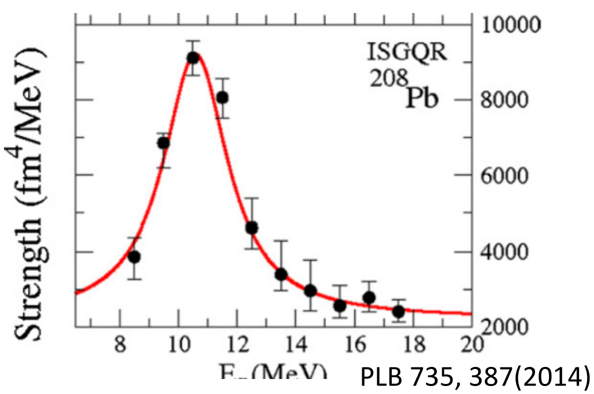
^{112}Sn(α,α’) (386 MeV α)



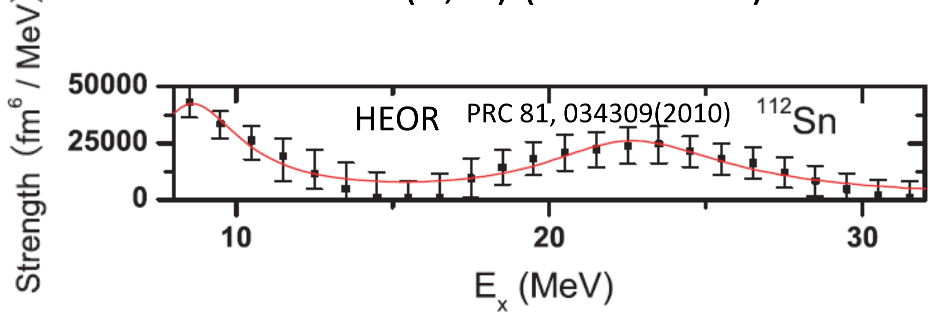
^{90}Zr(α,α’) (386 MeV α)



^{208}Pb(α,α’) (400 MeV α)



^{112}Sn(α,α’) (386 MeV α)



Importance

- The excitation energies of the resonances tell us about bulk properties of the nucleus.
- In particular, the Giant Monopole Resonance lets us calculate the incompressibility of the nucleus.

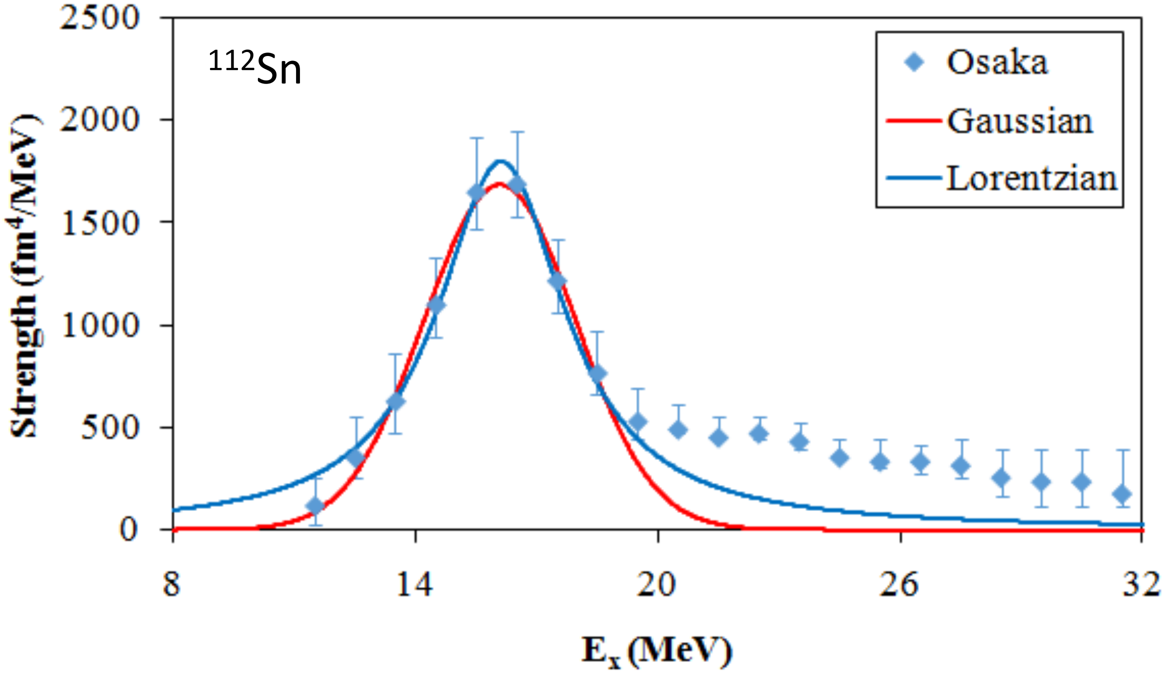
$$E_{ISGMR} = \frac{\hbar\sqrt{K_A}}{m\langle r^2\rangle}$$

Where E_{ISGMR} is the monopole excitation energy, m is the mass of the nucleus, $\langle r^2 \rangle$ is the ground-state mean-square radius, and K_A is the incompressibility of the nucleus.

Gaussian vs. Lorentzian

$$P(E_x, E_{cen}, A, \sigma) = Ae^{-\frac{(E_x - E_{cen})^2}{2\sigma^2}}$$

$$P(E_x, E_{cen}, A, \Gamma) = A\frac{\frac{\Gamma}{2}}{(E_x - E_{cen})^2 + \left(\frac{\Gamma}{2}\right)^2}$$



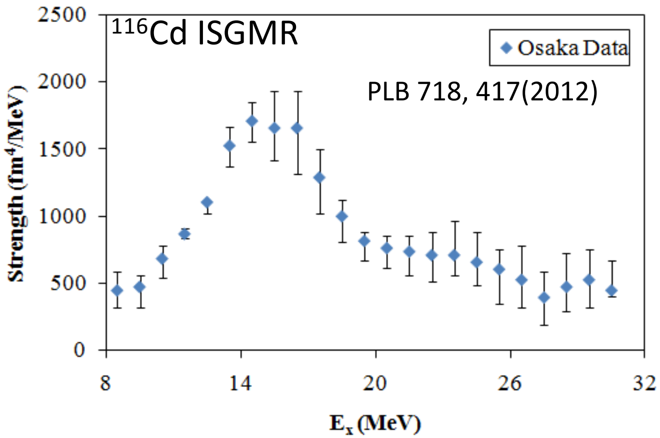
$$\Gamma = \sigma 2\sqrt{2\ln(2)}$$

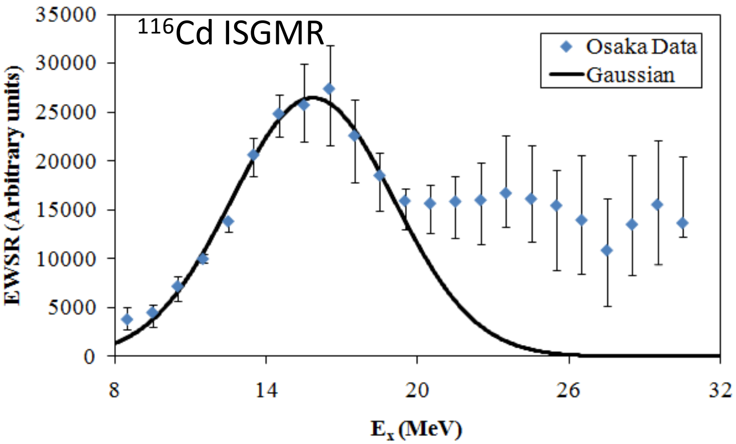
• The Lorentzian Distribution (Breit-Wigner Distribution) tails off much more than the Gaussian Distribution.

Strength vs. EWSR

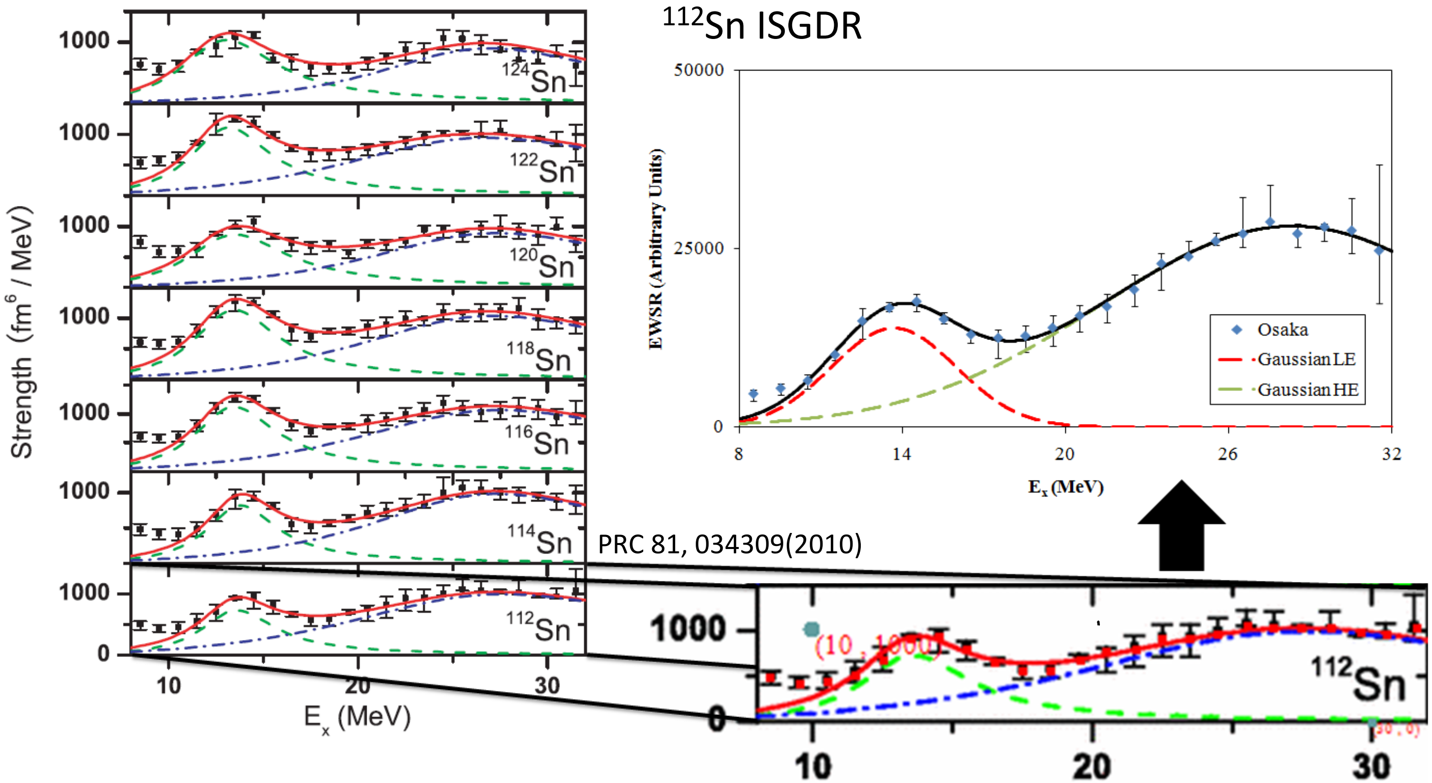
- Strength distribution [expressed as BE0(fm^4/MeV) for the monopole] shows the effective probability for excitation of the multipole as a function of energy.
- Energy Weighted Sum Rule: Theoretically, for a particular nucleus and multipolarity, when the strength is multiplied by the energy and then integrated over all energies the result will have a particular value.

$$\int_0^\infty (E_{x^*}BEL)\,\mathrm{d}E_x = EWSR_L$$





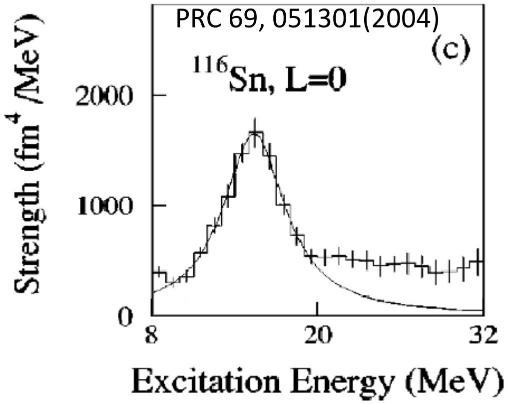
Data Extraction Process

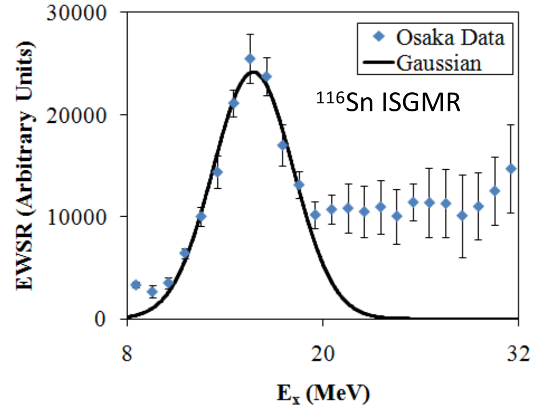


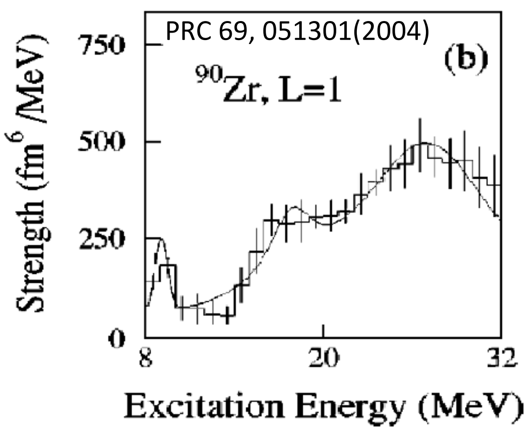
- All plots taken from publications by the Osaka group.
- Data from each plot were extracted using digitization software.
- After adjusting the data to a EWSR strength distribution, the resulting data were fit with a Gaussian distribution.
- This was done for 49 different giant resonances.

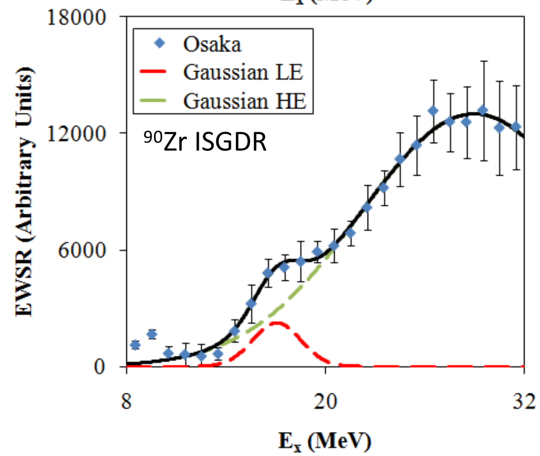
Converting Osaka data to EWSR distributions

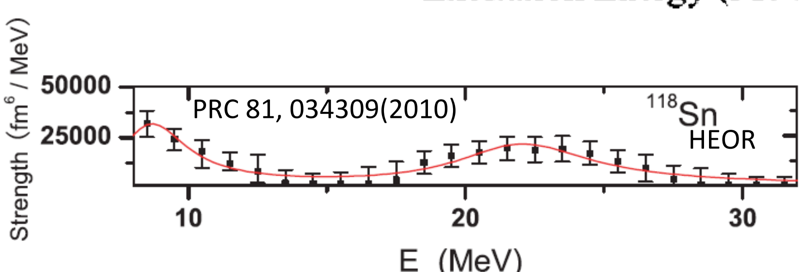
130% of EWSR

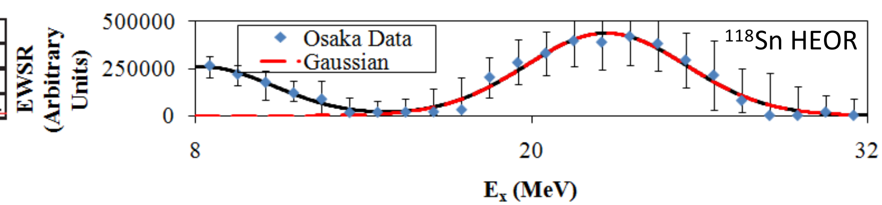






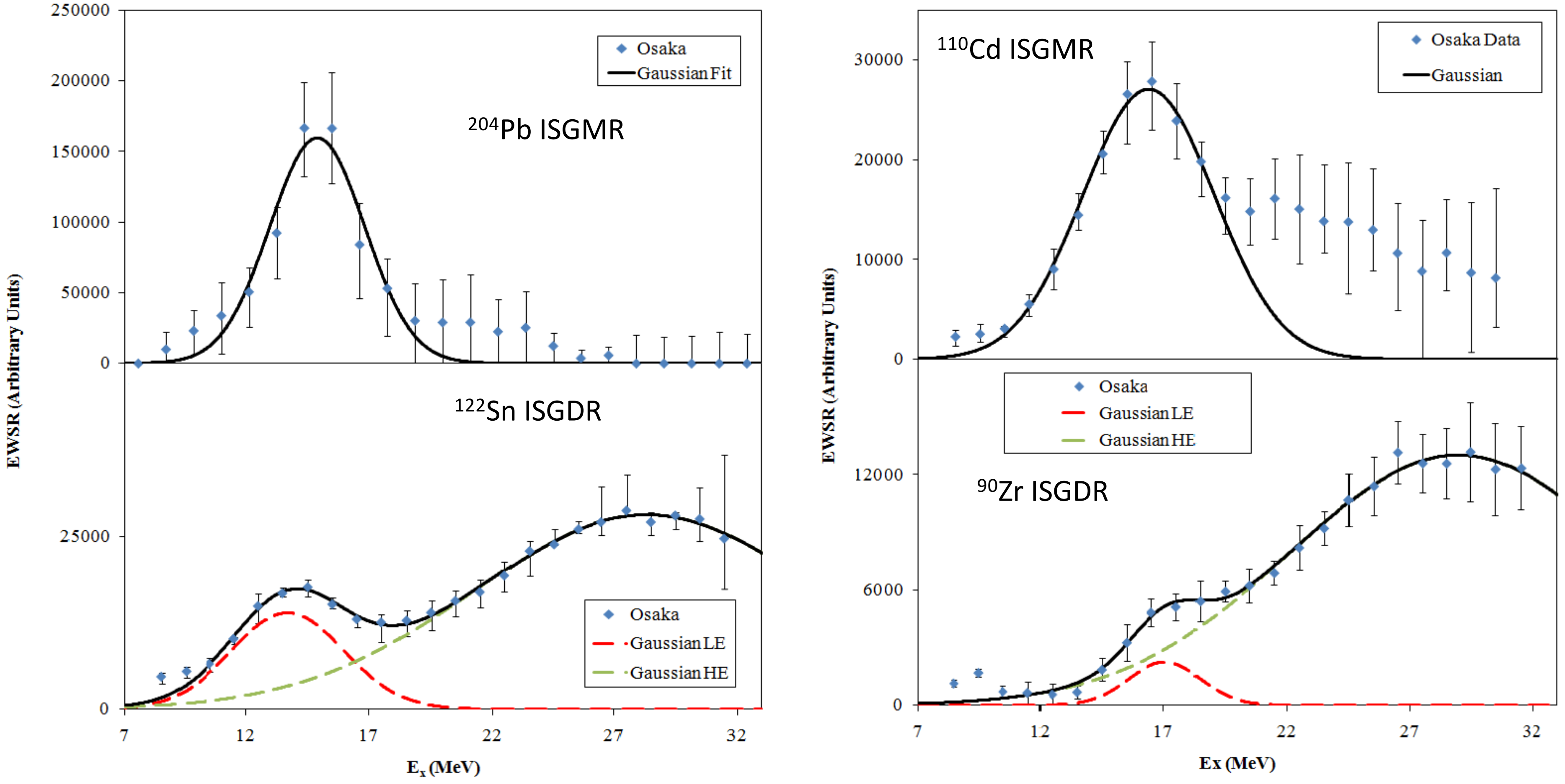






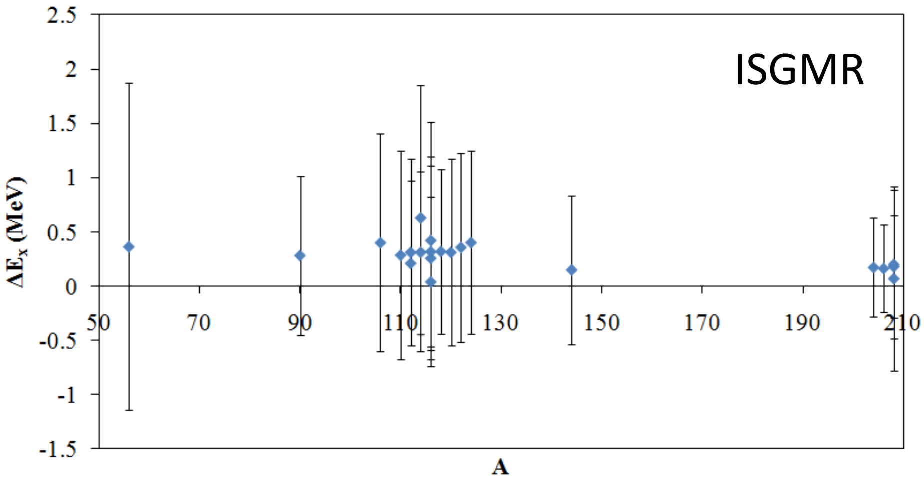
CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

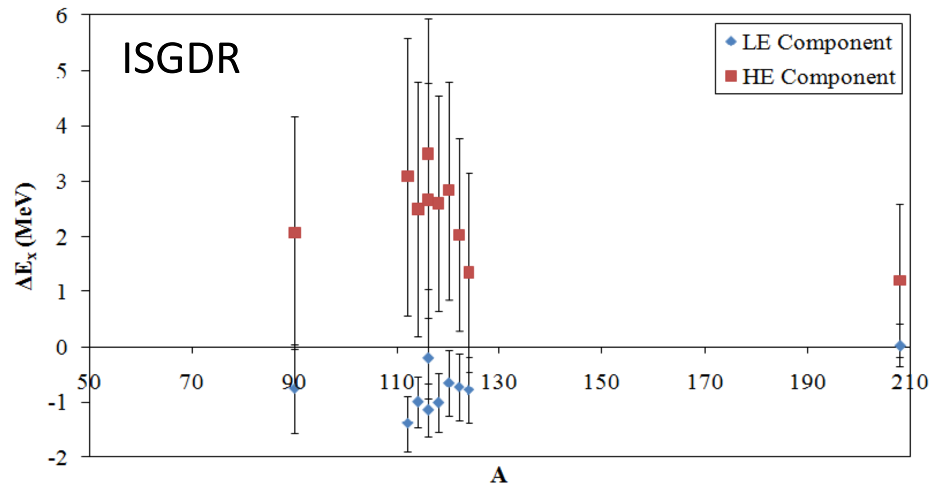
Fits

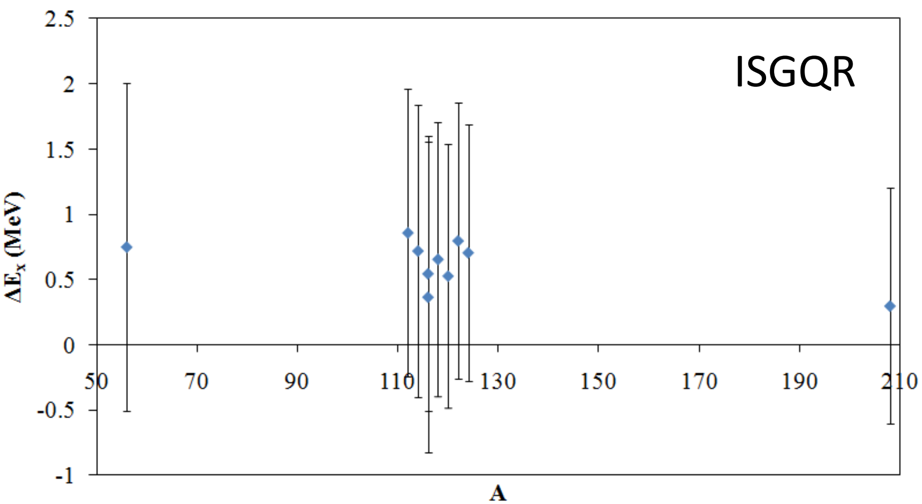


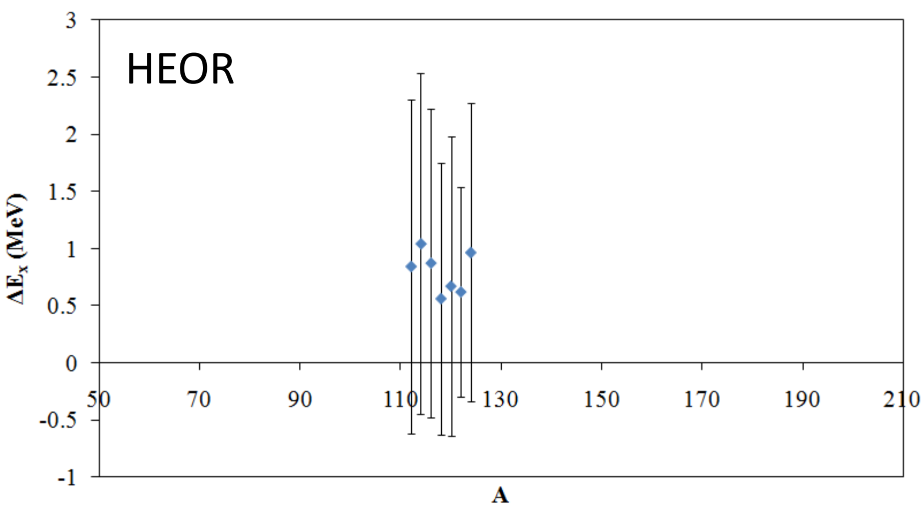
CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

$\Delta E_x = E_{x,ATS} - E_{x,Osaka}$

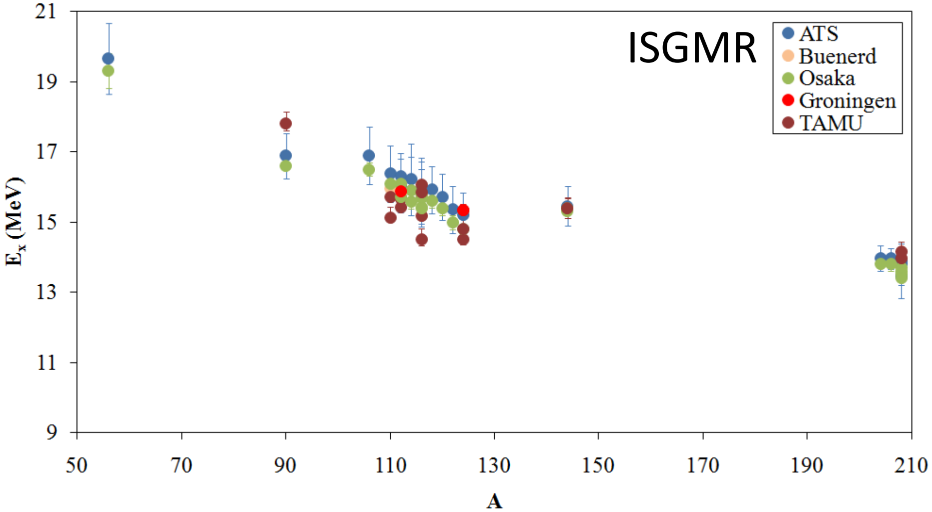


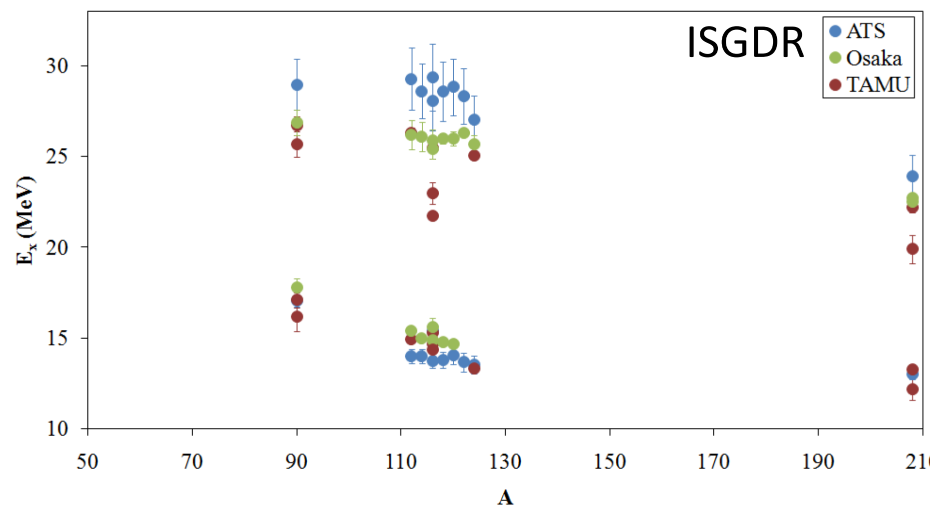


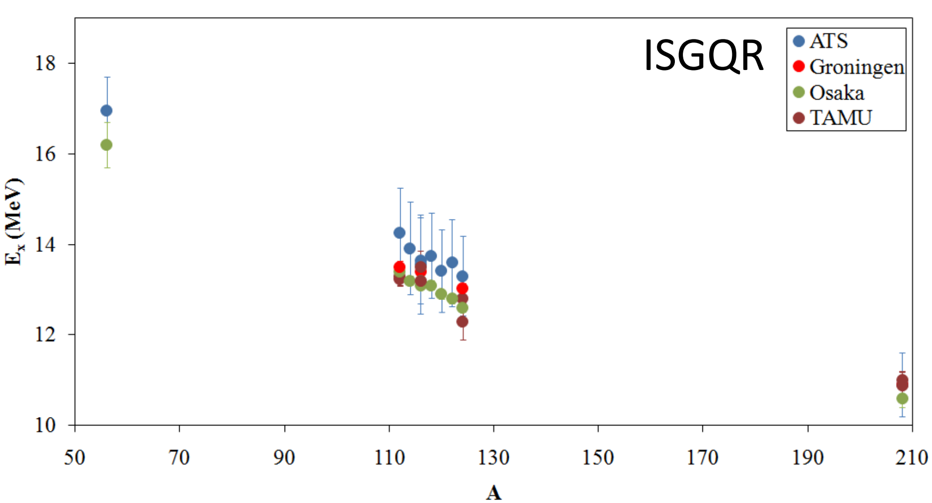


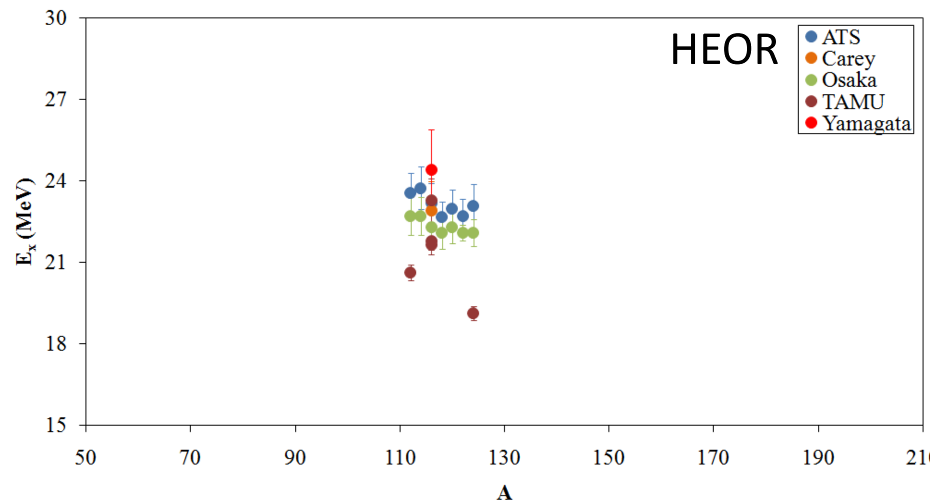


Resonances


ISGMR
ATS
Buenerd
Osaka
Groningen
TAMU
E_x (MeV)
21
19
17
15
13
11
9
50
70
90
110
130
150
170
190
210
A


ISGDR
ATS
Osaka
TAMU
E_x (MeV)
30
25
20
15
10
50
70
90
110
130
150
170
190
210
A


ISGQR
ATS
Groningen
Osaka
TAMU
E_x (MeV)
18
16
14
12
10
50
70
90
110
130
150
170
190
210
A


HEOR
ATS
Carey
Osaka
TAMU
Yamagata
E_x (MeV)
30
27
24
21
18
15
50
70
90
110
130
150
170
190
210
A

Conclusion

- The centroids obtained from the Gaussian fits to the EWSR strength distributions are generally higher than the energies reported by the Osaka group, however in most cases are well within the uncertainties.
- The Gaussian fit to the EWSR distributions for the high energy ISGDR data results in 1-4 MeV higher energies than the fits to the radiative strengths, primarily due to the large widths of these resonances.

CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

Acknowledgements

TAMU Cyclotron Institute REU Program, funded through National Science Foundation grant PHY-1263281 and Department of Energy grant DE-FG03-93ER40773.

Graph References

- Buenerd: J. Phys. (Paris), Colloq. 45, C4-115 (1984).
- Carey: Phys. Rev. Let. 45, 239(1980).
- Groningen: Nucl. Phys. A 466, 29(1987).
  Phys. Rev. C 38, 2562(1988).
- Osaka: Phys. Rev. C 68, 064602(2003); 69, 051301(2004); 81, 034309(2010).
  Phys. Rev. Let. 100, 042501(2008).
  Phys. Let. B 549, 58(2002); 557, 12(2003); 718, 417(2012); 726, 178(2013); 735, 387(2014).
- TAMU: Phys. Rev. C 23, 1997(1981); 54, 72(1996); 63, 031301(2001); 69, 034315(2004); 69, 034611(2004); 69, 054312(2004); 70, 014307(2004); 79, 024320(2009).
  Phys. Rev. Let. 82, 691(1999).
- Yamagata: Phys. Rev. C 23, 937(1981).