Z=50 shell gap near doubly magic ^{100}Sn

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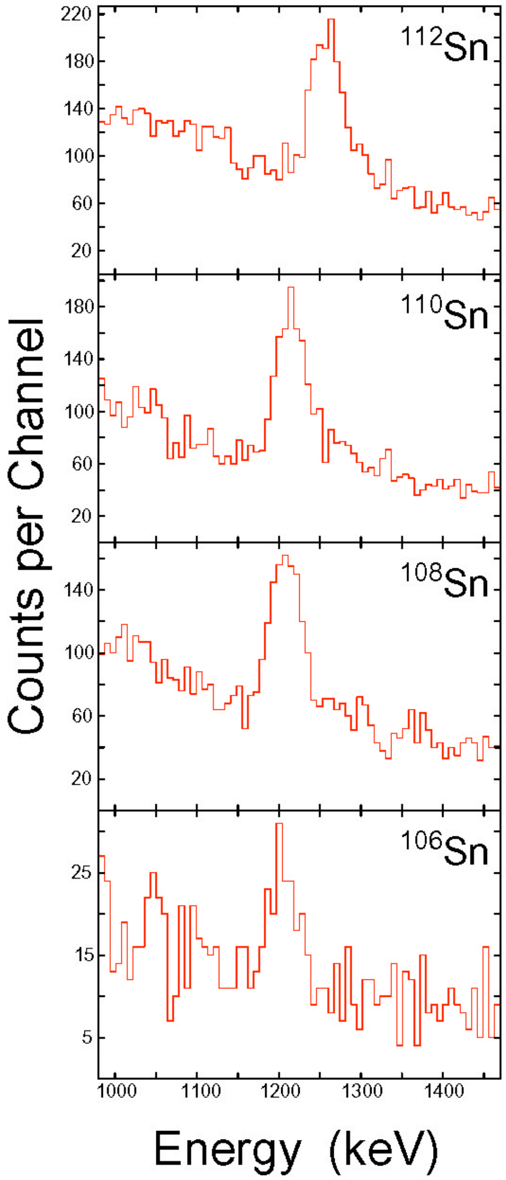
N=Z nuclei

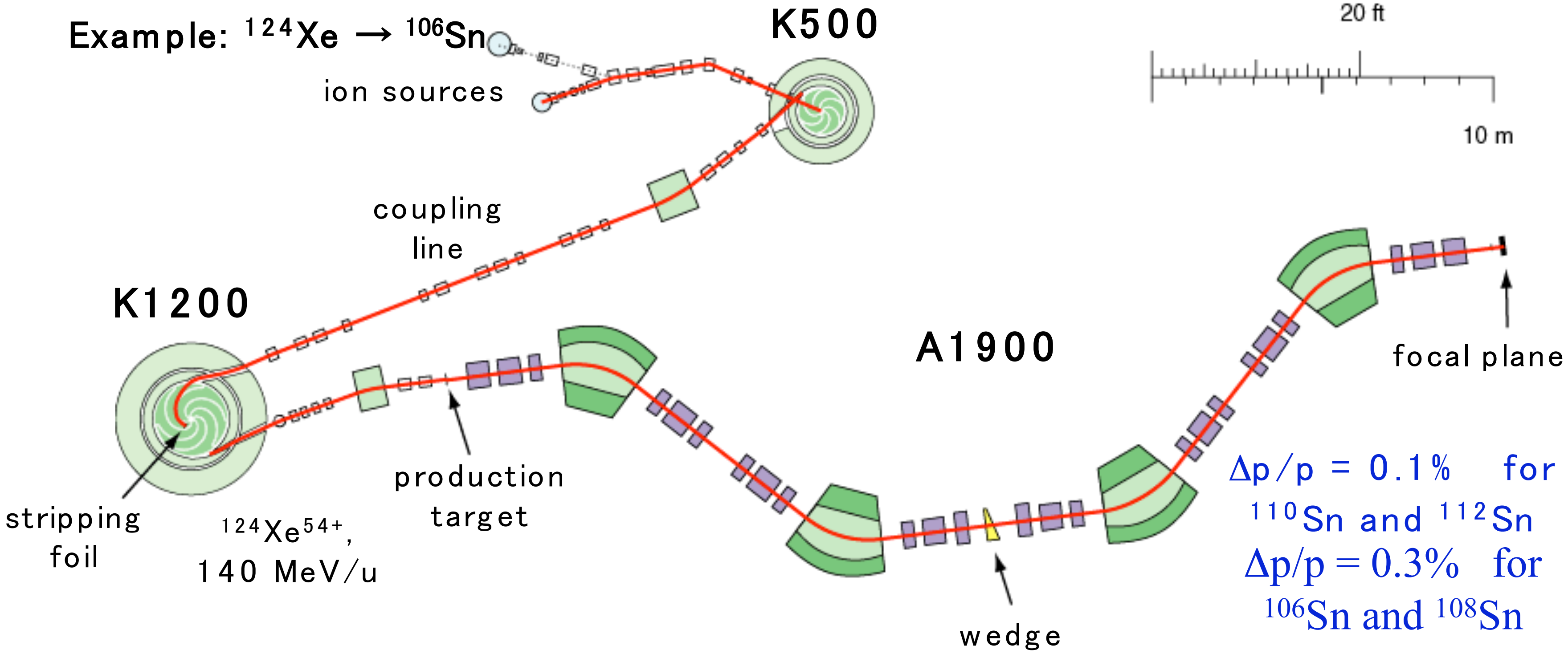
- **Protons and neutrons fill the same shells.**
- **Enhanced proton-neutron interactions.**
- **Isospin symmetry.**
- **Attractive benchmarks for nuclear theory.**

The NSCL 03011 experiment

- **Transition probability measurements in light Sn isotopes are hindered by the presence of a nanosecond-lifetime isomeric state at spin 6^+.**
- **The first excited 2^+_1 states, with picoseconds lifetimes, must be populated directly from the ground state.**
- **Coulomb excitation is a method of choice if beams of unstable light Sn nuclei can be provided.**
- **The NSCL experiment 03011 employed the intermediate energy Coulomb excitations to study transition probability to the first excited state in ^{106}Sn, ^{108}Sn, ^{110}Sn, ^{112}Sn on a thick ^{197}Au target.**



In-Flight Production or Rare Isotopes

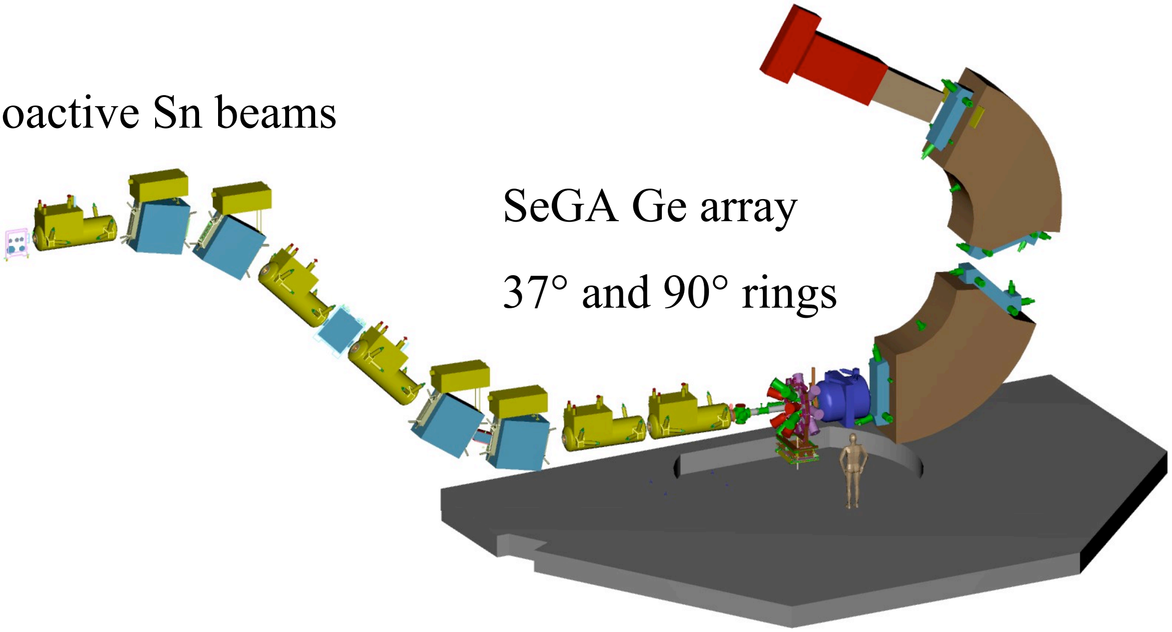


$\Delta p/p = 0.1\%$ for ^{110}Sn and ^{112}Sn

$\Delta p/p = 0.3\%$ for ^{106}Sn and ^{108}Sn

- **Particles are identified on the event-by-event basis from the time of flight and energy loss measurement in A1900/S800 spectrometers.**

Experimental setup: S800 + SeGA



S800 Focal plane

Incoming radioactive Sn beams

SeGA Ge array

37° and 90° rings

- **S800 spectrograph to charaterize particles after reaction**
- **SeGA Ge array to measure doppler-corrected γ-ray energy**

Coulex scaling to target excitation

- ^{106}Sn and ^{197}Au from the same kinematic gate,
- $\sigma(E2, I_i \rightarrow I_f) \sim (Z_{pro})^2\, B(E2, I_i \rightarrow I_f) / (b_{min})^2$,
- b_{min} is the same for the projectile and target,
- therefore:

$$\frac{\sigma^{106}{}^{Sn}(E2, 0^+ \rightarrow 2^+)}{\sigma^{197}{}^{Au}(E2, \tfrac{3}{2}^+ \rightarrow \tfrac{7}{2}^+)} = \left(\frac{Z^{197}{}^{Au}}{Z^{106}{}^{Sn}}\right)^2 \frac{B^{106}{}^{Sn}(E2, 0^+ \rightarrow 2^+)}{B^{197}{}^{Au}(E2, \tfrac{3}{2}^+ \rightarrow \tfrac{7}{2}^+)}$$

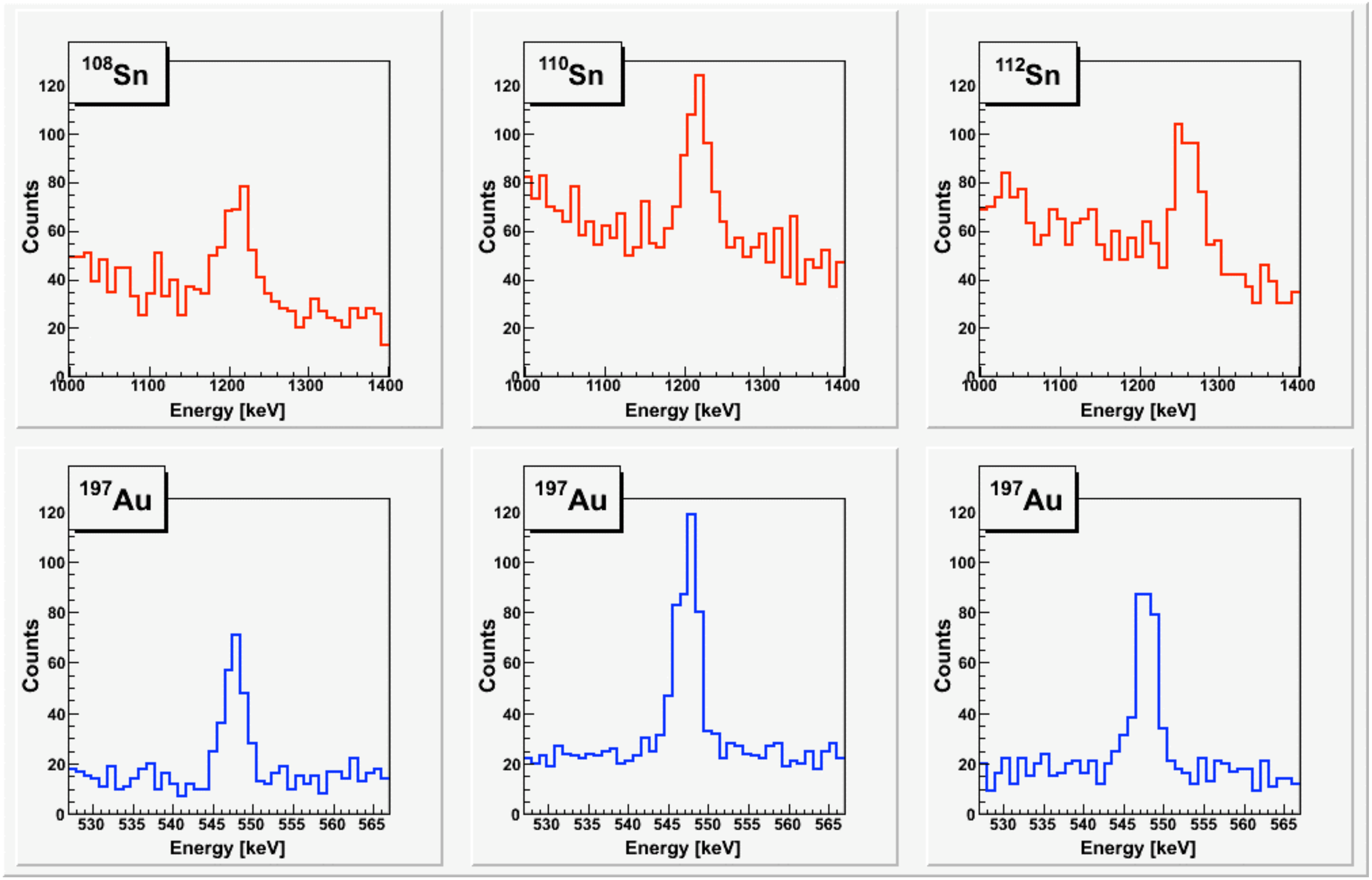
- Ratio of the cross sections from corresponding γ-ray intensities.
- Scaling sensitive to relative γ-ray efficiency for the Sn and Au excitation.

Data analysis for ^{108}Sn-^{112}Sn

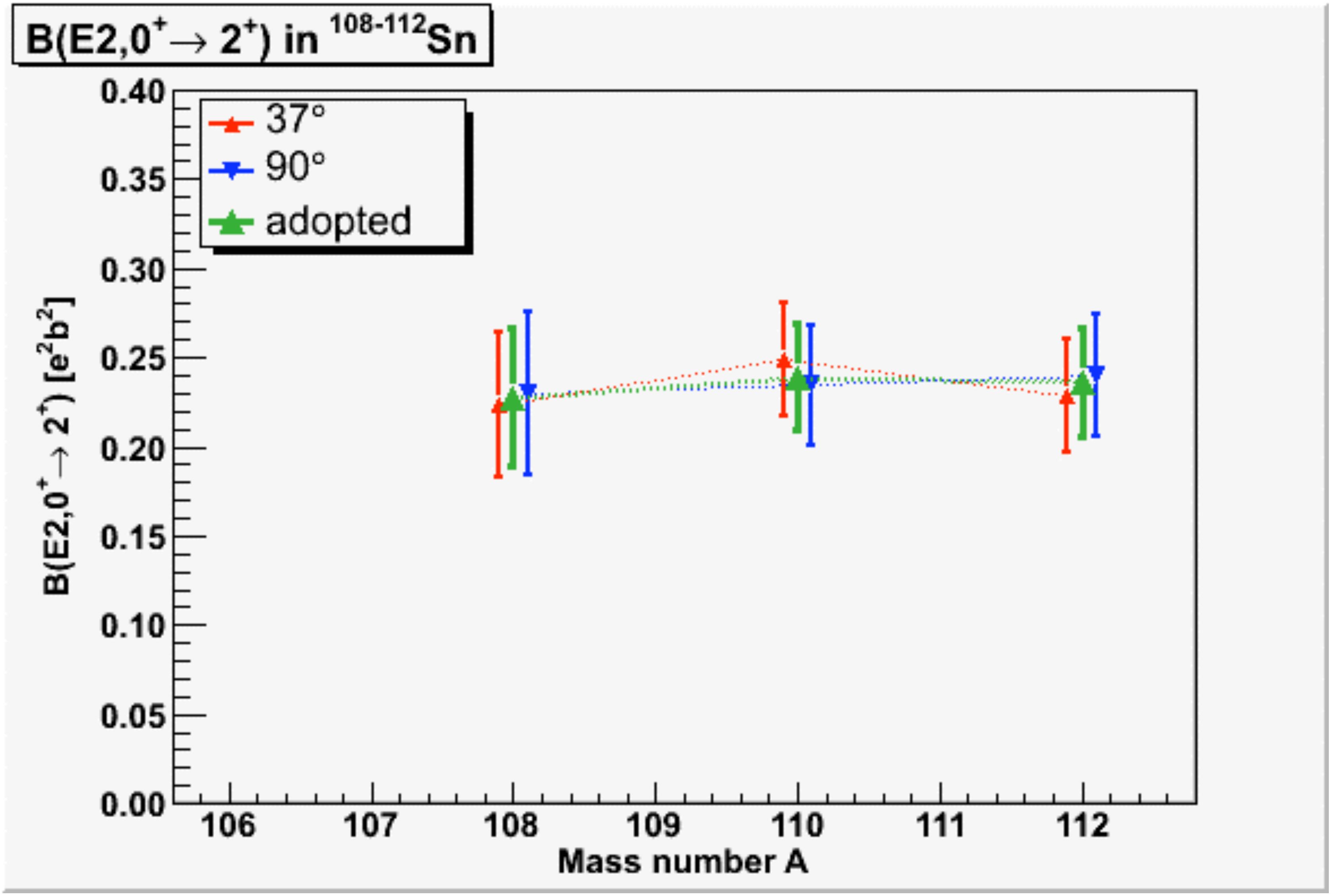
- Avoid nuclear interference by selecting large impact parameter: b_{min}> 19.5 fm, θ_{LAB}<45 mrad, θ_{CM}<72 mrad.
- For each isotope measure the B(E2) relative to the ^{197}Au target excitation.
- Analyze the data from the two SeGA rings separately, examine the trend as a function of the mass number.
- Use data on ^{112}Sn as a test case for which the B(E2) is very well known.

Data analysis for ^{108}Sn-^{112}Sn

SeGA ring at 90^{o}



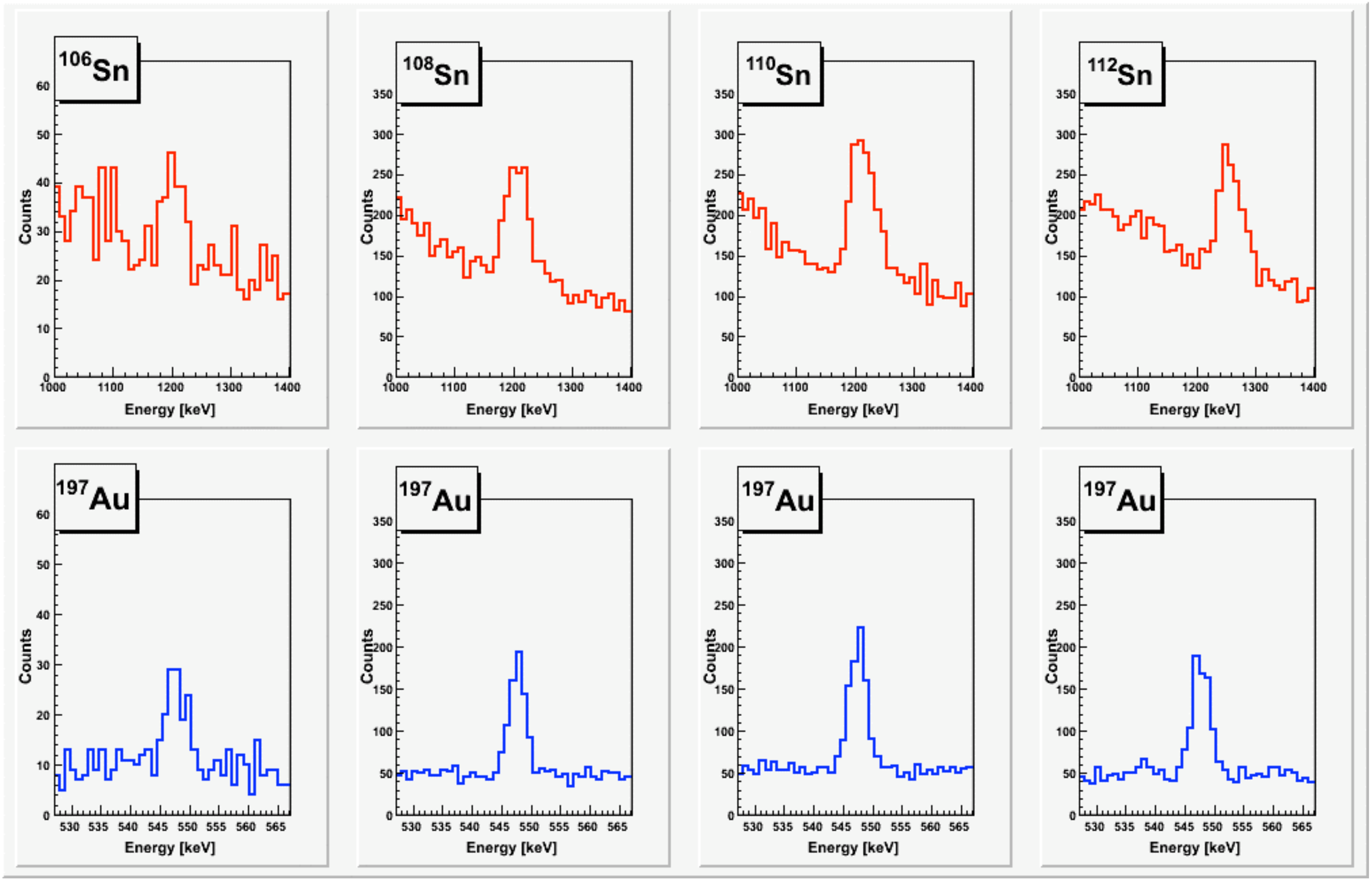
Data analysis for ^{108}Sn-^{112}Sn



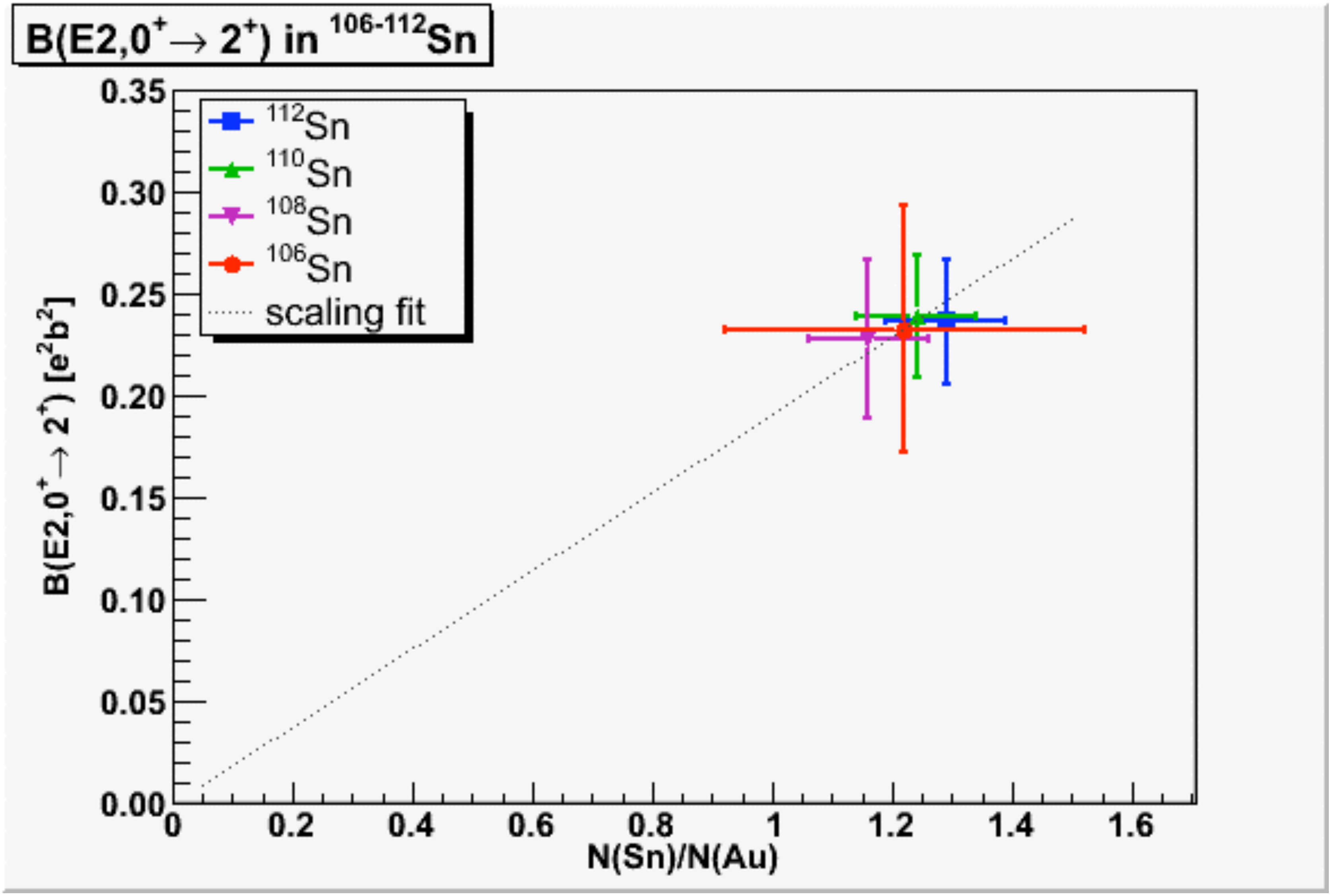
Data analysis for ^{106}Sn-^{112}Sn

- Impact parameter condition has to be released for ^{106}Sn to get enough statistics.
- Nuclear excitation expected to be smaller than Coulomb excitation and similar for ^{106}Sn-^{112}Sn.
- Scale the number of counts in $^{106\text{-}112}$Sn to the target excitation to remove dependence on reaction kinematics.
- Work out the scaling factor between the above ratio and $B(E2,0^+\rightarrow2^+)$ measured for $^{108\text{-}112}$Sn.
- Apply this scaling factor to the data on ^{106}Sn to obtain the corresponding B(E2).

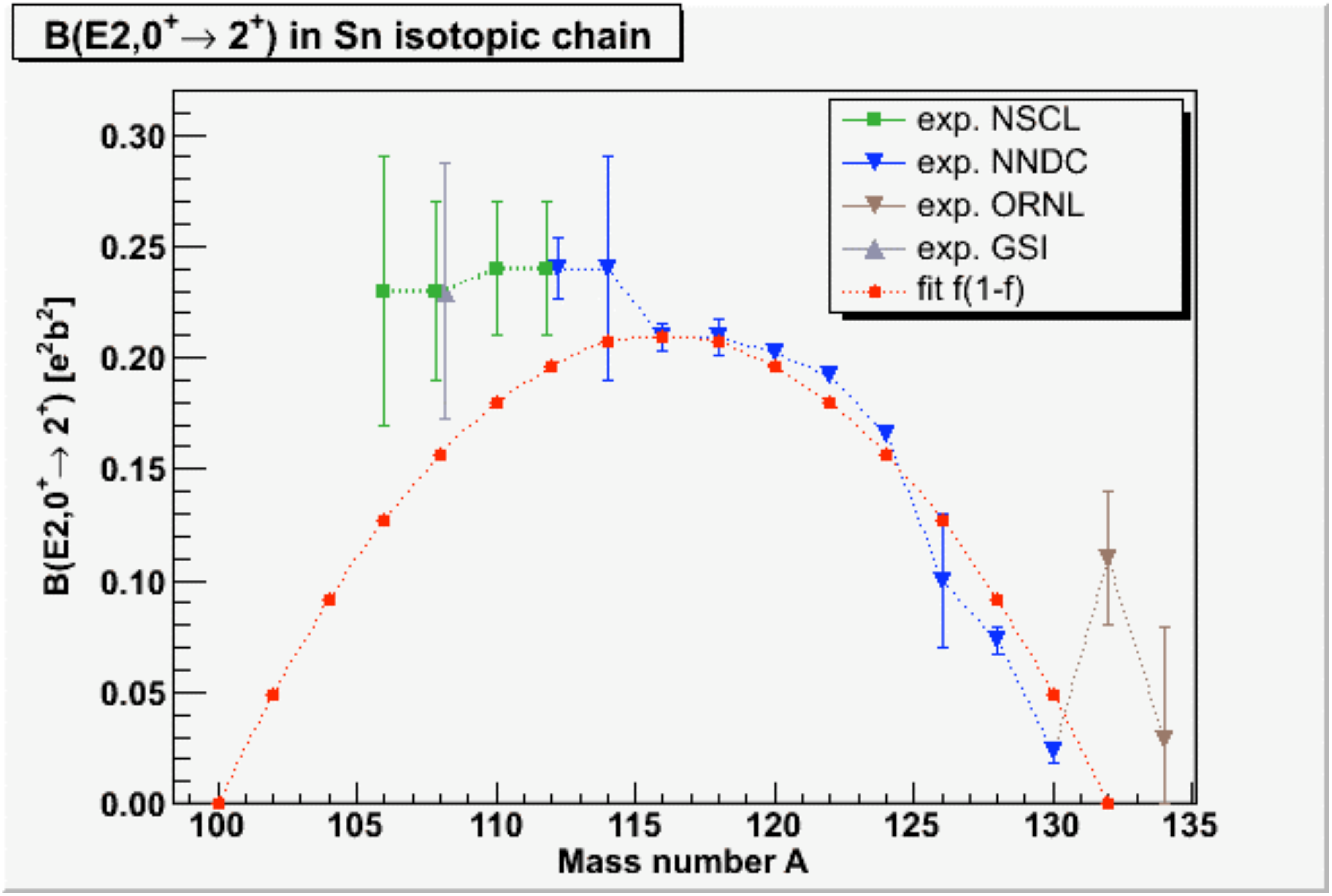
Data analysis for ^{106}Sn-^{112}Sn



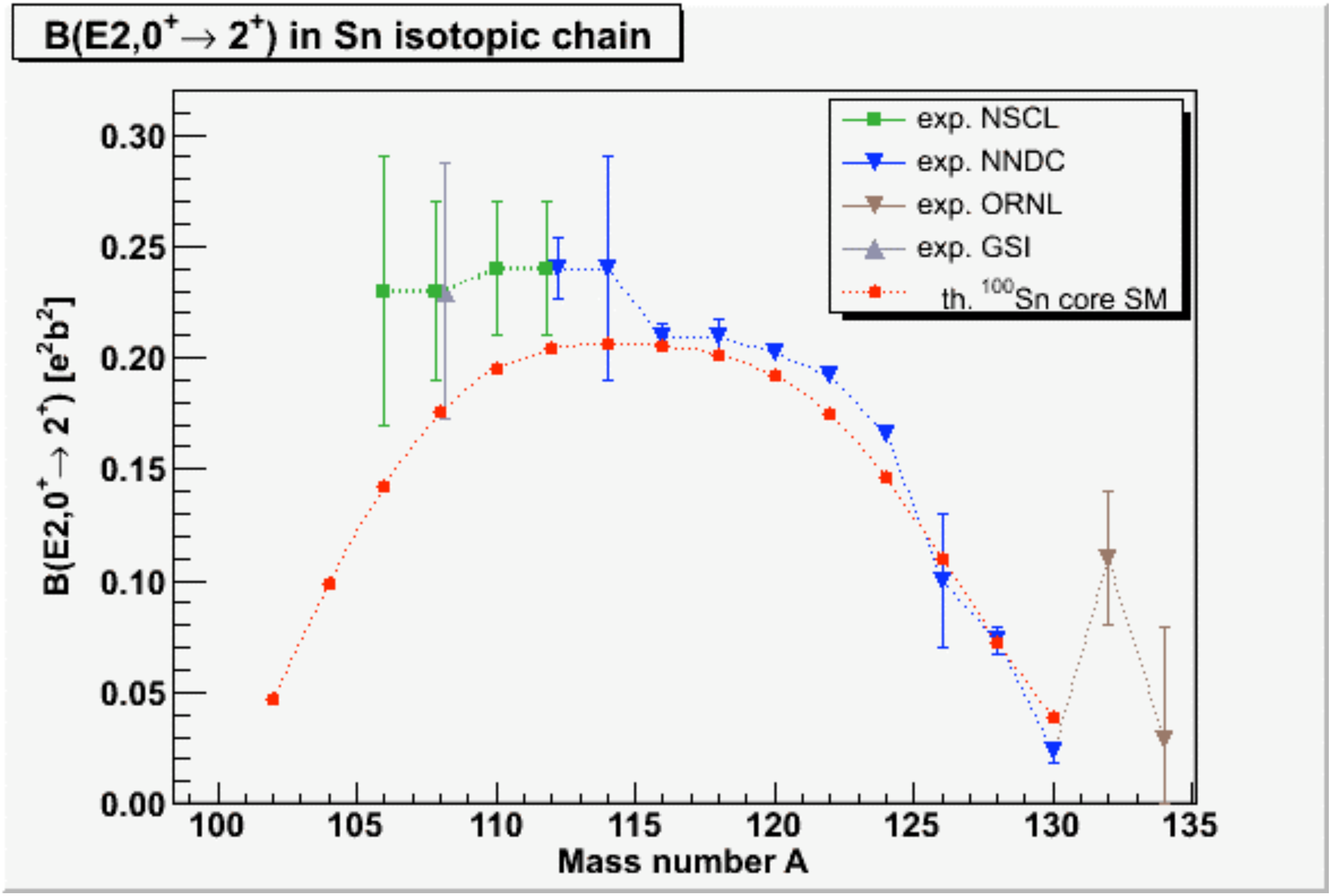
Data analysis for ^{106}Sn-^{112}Sn



^{106}Sn-^{112}Sn adopted B(E2,0$^+$→2$^+$)

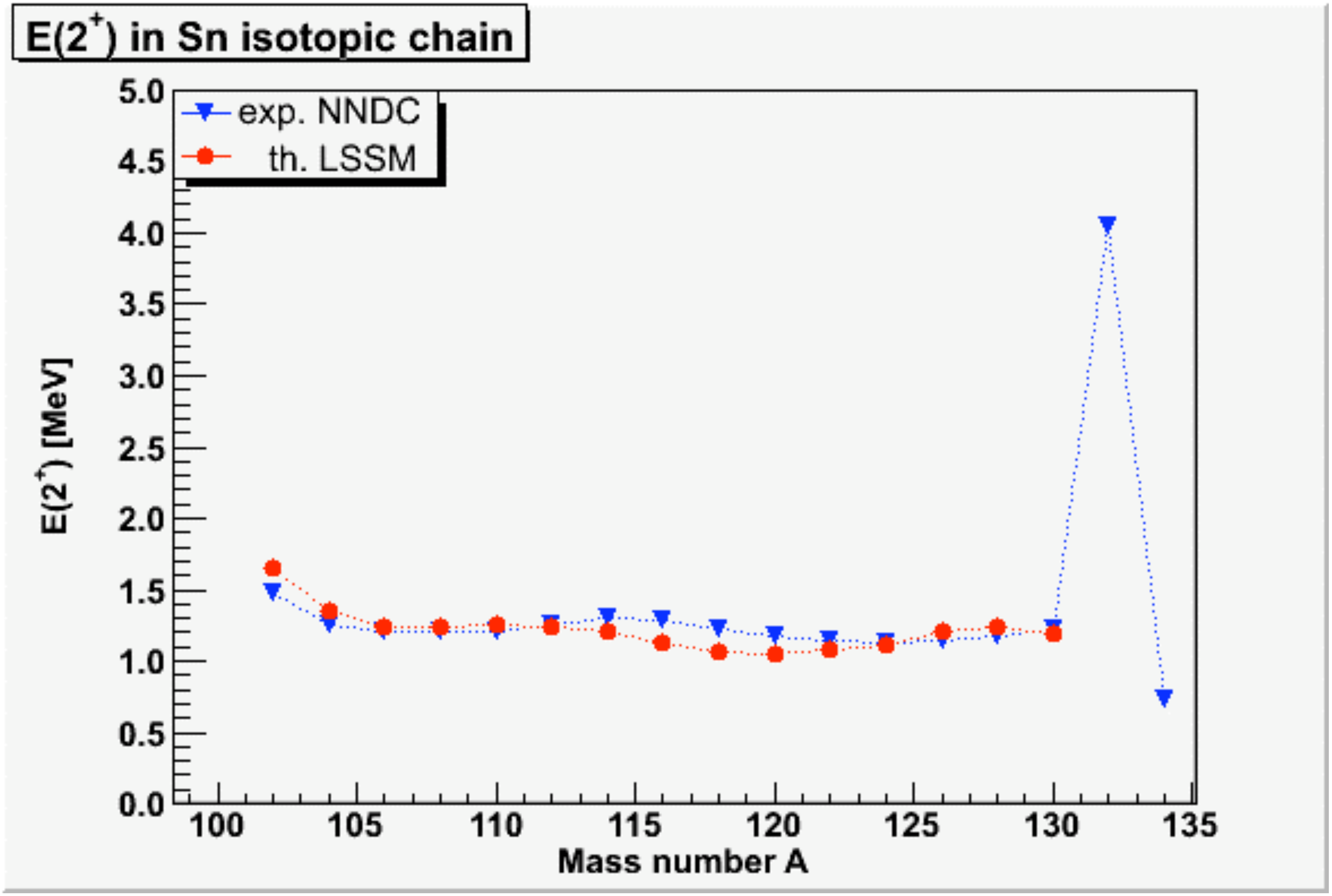


Shell model predictions from before 03011



M. Hjort-Jensen, private communication

Large Scale Shell Model calculations



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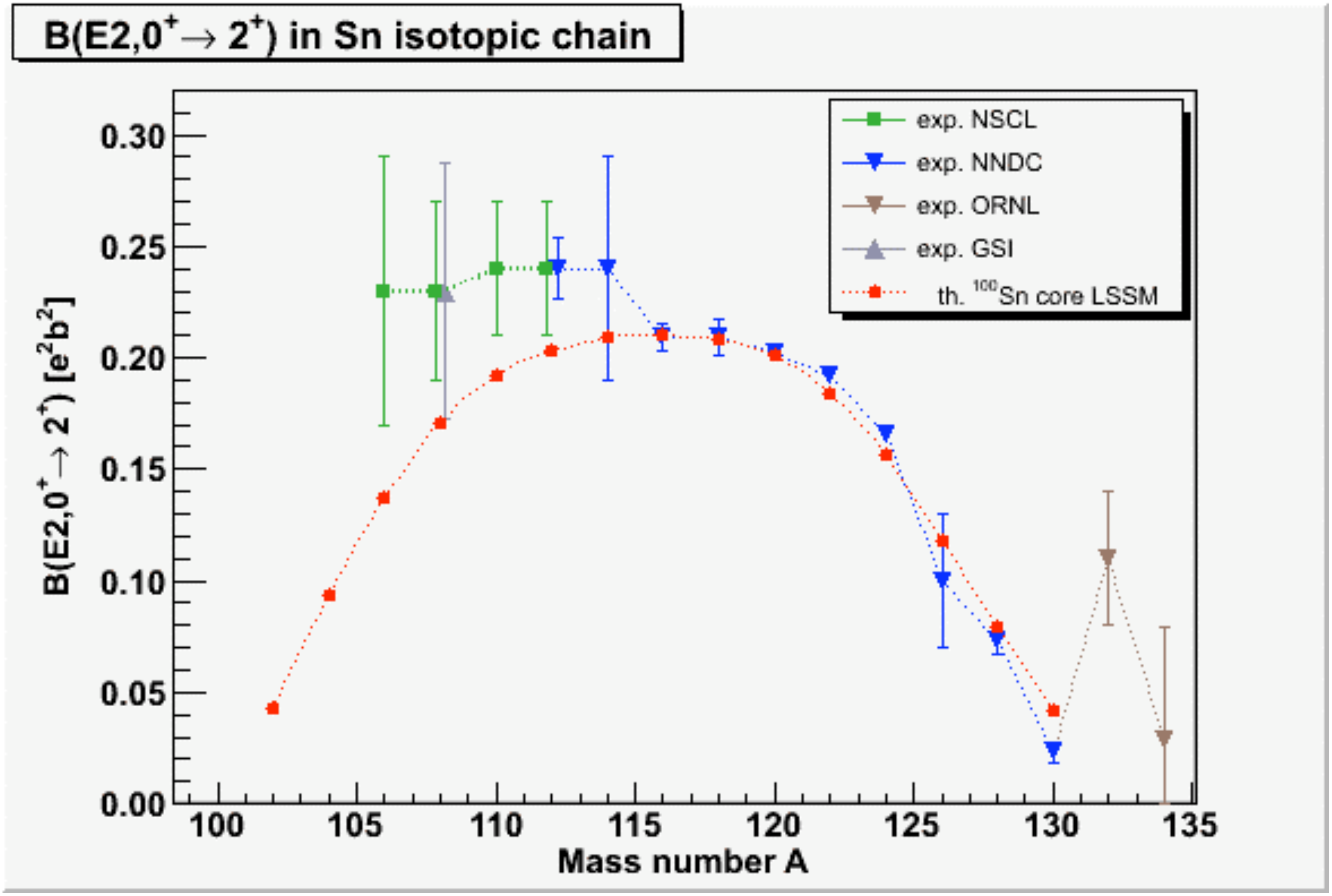
Large Scale Shell Model calculations



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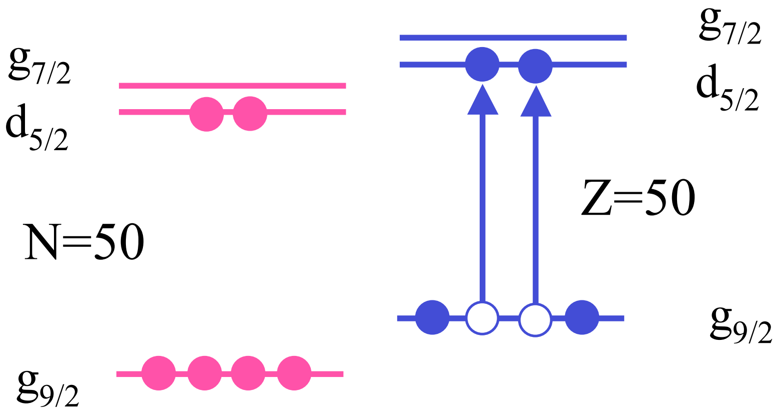
Interacting orbitals across the Z=N=50 shell gap

- **Quadrupole-quadrupole interaction.**
- **The lowest order long-range term from multipole decomposition of effective nuclear interactions.**
- **Interaction in the particle-hole channel.**
- **Large matrix element for Δl=2, Δj=2 orbitals.**



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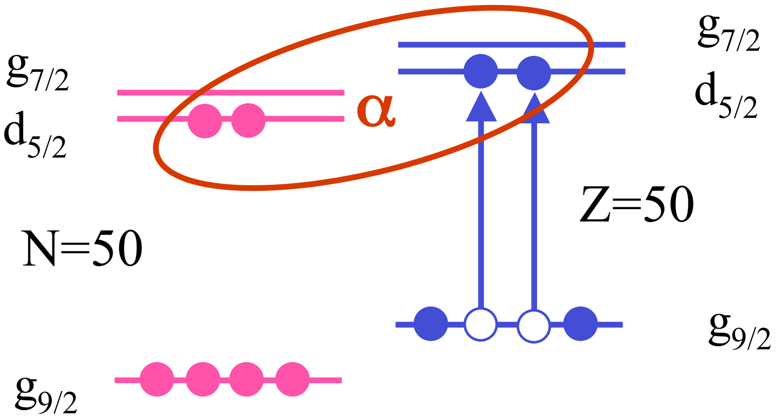
2p2h excitations in light Sn near N=50

- Large α-like correlation for 2p2h proton excitations.
- ~70%/30% mixture of the 0p0h and 2p2h excitations in the ground state.
- Enhancement in the B(E2) transition rates from proton contributions. !
- Active only when neutrons fill lower part of the $d_{5/2}g_{7/2}$ shell. !
- Low-lying 0^+state associated with the 2p2h excitations. !
- Collective bands built on the 2p2h configurations. !
- Smooth band termination of these bands due to the limited valence space. !
- Analogy with Ni chain at Z=28 near N=28.



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Summary

- B(E2,$0^+ \rightarrow 2^+$) in $^{106-112}$Sn were measured in a single experiment from intermediate energy Coulomb excitation.

- The sensitivity of the NSCL allowed for a measurement in ^{106}Sn, only 6 neutron away from the doubly magic ^{100}Sn.

- The constant trend in excitation probability for the neutron number approaching N=50 indicates presence of substantial proton excitations across the Z=50 shell gap in the ground state of $^{106-112}$Sn isotopes. This implies breaking of the doubly magic ^{100}Sn core.

- The results are in disagreement with current state of the art calculations, a plausible qualitative explanation of the observed B(E2) enhancement awaits theoretical investigations.

Credits

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