Fine Structure Of The Isoscalar Giant Quadrupole Resonance And Fragmentation Of E2 Strengths in ^{28}Si And ^{27}Al*

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On behalf of
iThemba/Wits/UCT/RCNP/IKP-TU-Darmstadt K600 Group

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UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

NRF National Research Foundation

iThemba LABS Laboratory for Accelerator Based Sciences

DFG Deutsche Forschungsgemeinschaft

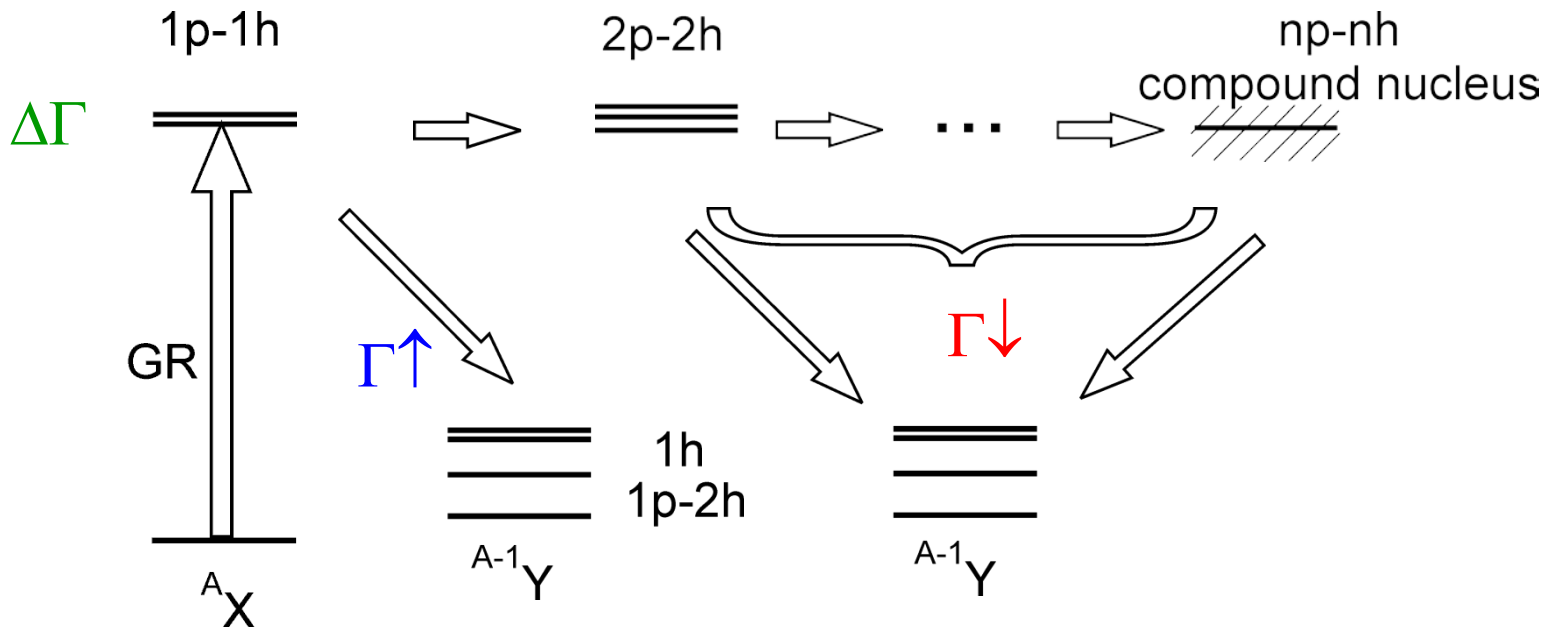
Outline

- Fine structure of Giant Resonances
- High energy-resolution experiments with K600 Magnetic Spectrometer of iThemba LABS
- Extracted Energy Scales and Comparison in ^{28}Si and ^{27}Al using Wavelet Analysis techniques
- Summary

Fine Structure of Giant Resonances

- Have been established as a Global phenomenon in
  - nuclei across the periodic table
  - other resonances
- Dominant processes of the decay?
- Spin- and parity-resolved level densities at high excitation energies?

Contribution to the width of giant resonances



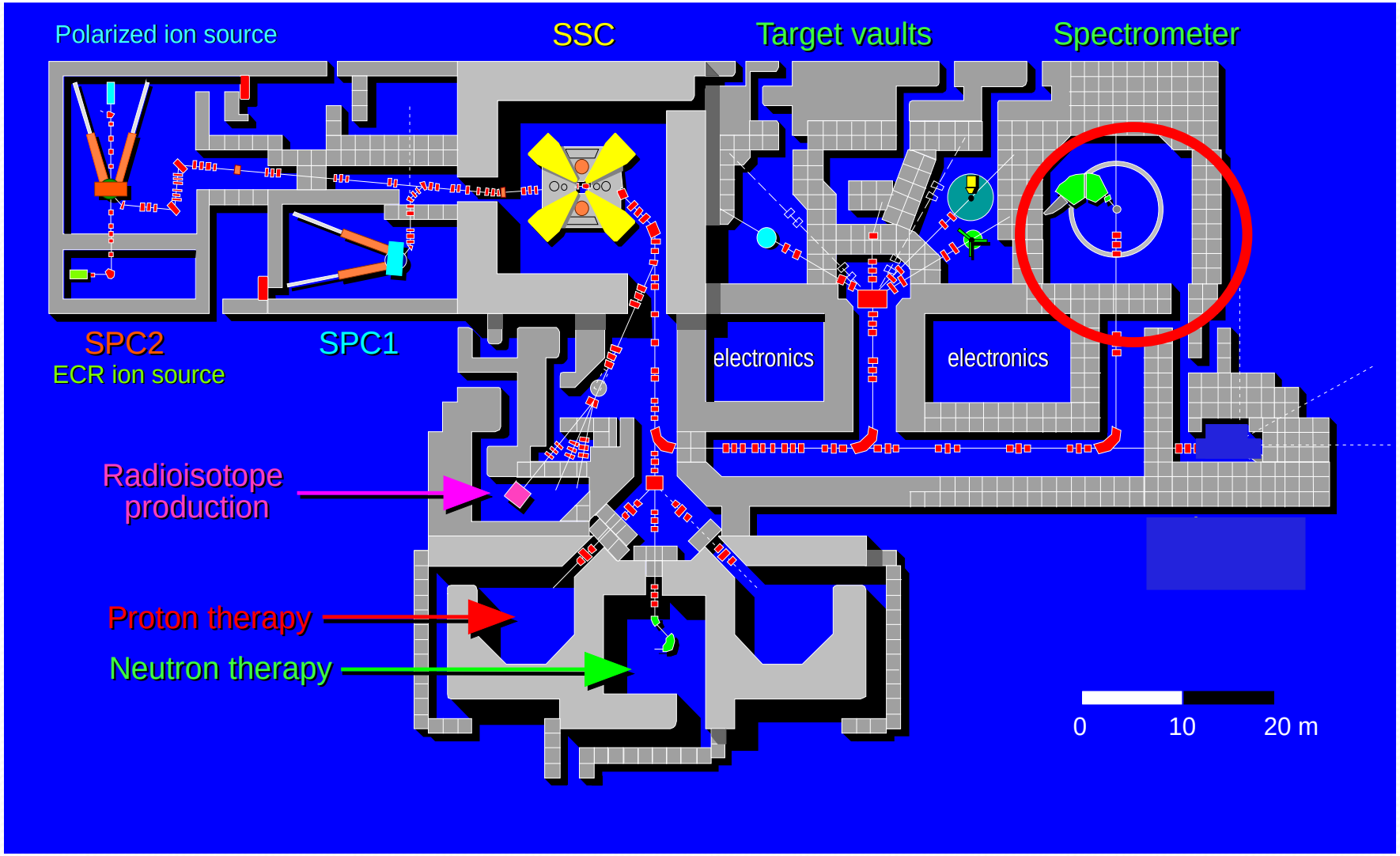
Direct decay

Pre-equilibrium and statistical decay

$$\Gamma = \Delta\Gamma + \Gamma\uparrow + \Gamma\downarrow$$

Resonance width	Landau damping	Escape width	Spreading width

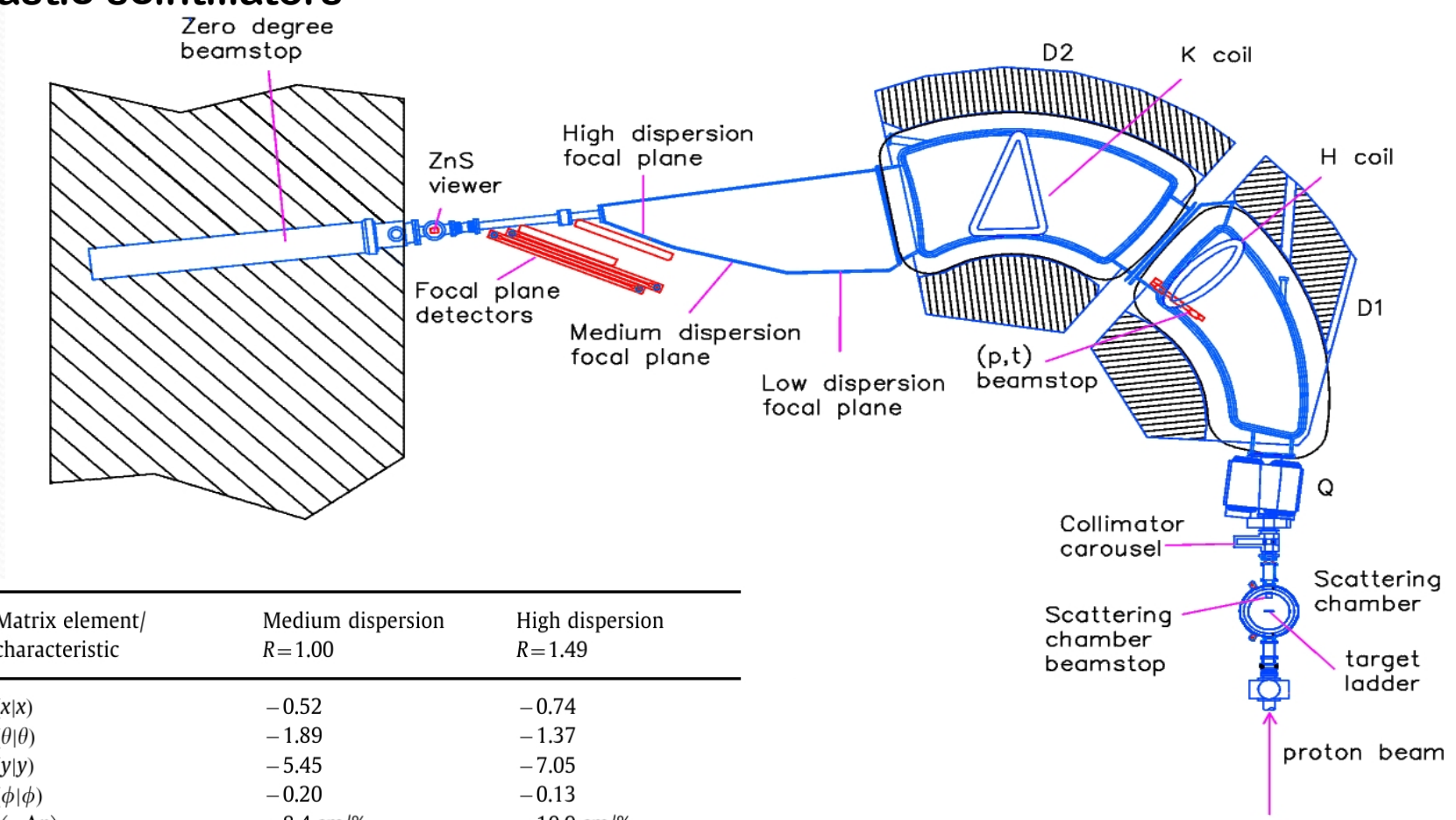
iThemba LABS Cyclotron Facility



K600 magnetic spectrometer at 0°

Focal plane detectors:
2 multiwire drift chambers (U and X wireplanes)
2 plastic scintillators

(p,p') setup: B(D1)/B(D2)=1.5
(p,t) setup: B(D1)/B(D2) = 1



Matrix element/ characteristic	Medium dispersion $R=1.00$	High dispersion $R=1.49$
$(x\|x)$	-0.52	-0.74
$(\theta\|\theta)$	-1.89	-1.37
$(y\|y)$	-5.45	-7.05
$(\phi\|\phi)$	-0.20	-0.13
$\left(x\|\frac{\Delta p}{p}\right)$	-8.4 cm/%	-10.9 cm/%
p_{max}/p_{min}	1.097	1.048

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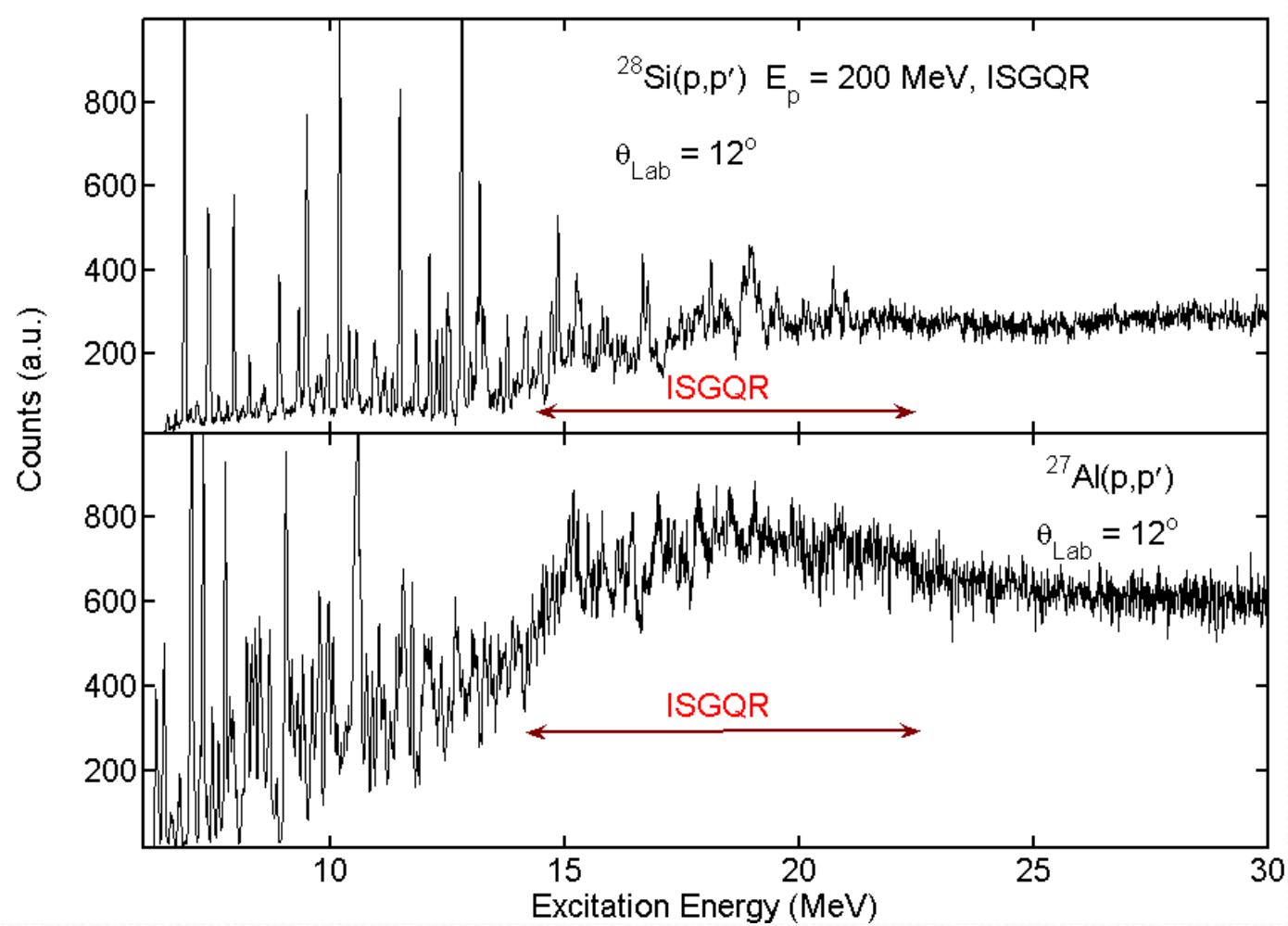
Fine structure of the ISGQR



ΔE = 38 keV

Excitation energy spectra at angles corresponding to the maximum of the ISGQR in ^{28}Si and ^{27}Al.

Wavelet Analysis

- Wavelets:

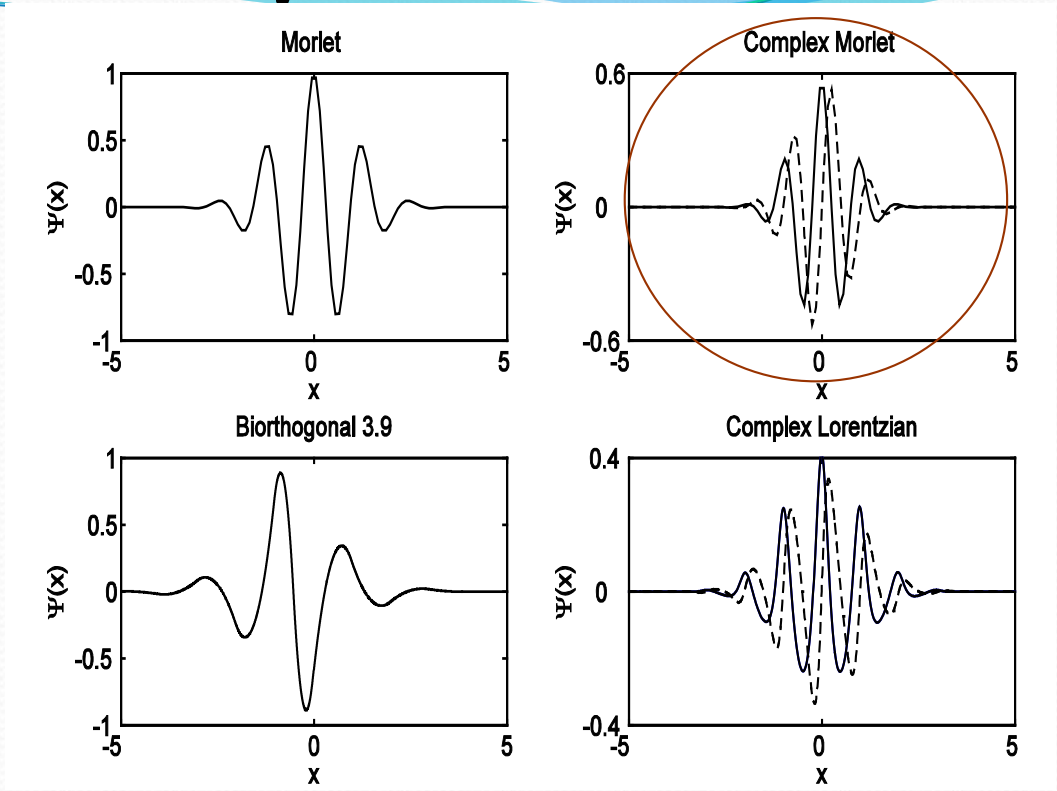
$$\int_{-\infty}^{\infty} \Psi(x)dx = 0$$

$$\int_{-\infty}^{\infty} \left|\Psi(x)\right|^2 dx < \infty$$

- Wavelet coefficients:

$$C(E_x, \delta E) = \frac{1}{\sqrt{\delta E}} \int \sigma(E) \Psi\left(\frac{E_x - E}{\delta E}\right) dE$$

Position Scale **Spectrum** **Wavelet**



- Morlet:

$$\Psi(x) = \frac{1}{\pi^{1/4}} \cos(ikx) \exp\left(-\frac{x^2}{2}\right)$$

- Complex Morlet:

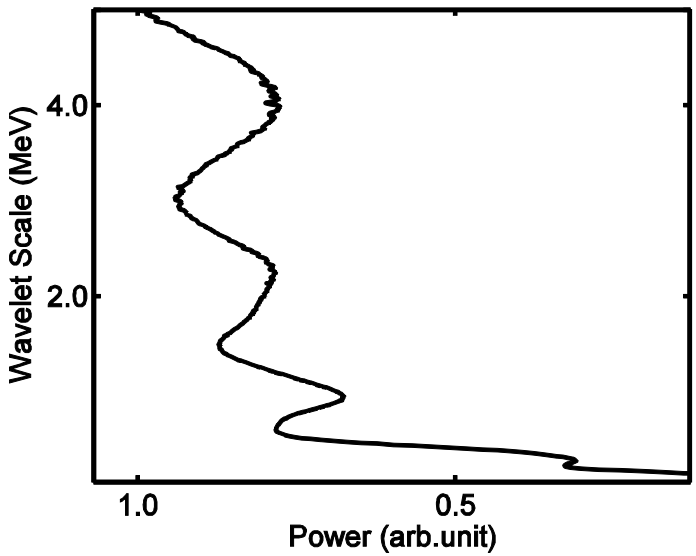
$$\Psi(x) = \frac{1}{\sqrt{\pi f_b}} \exp(2\pi i f_c) \exp\left(-\frac{x^2}{f_b}\right)$$

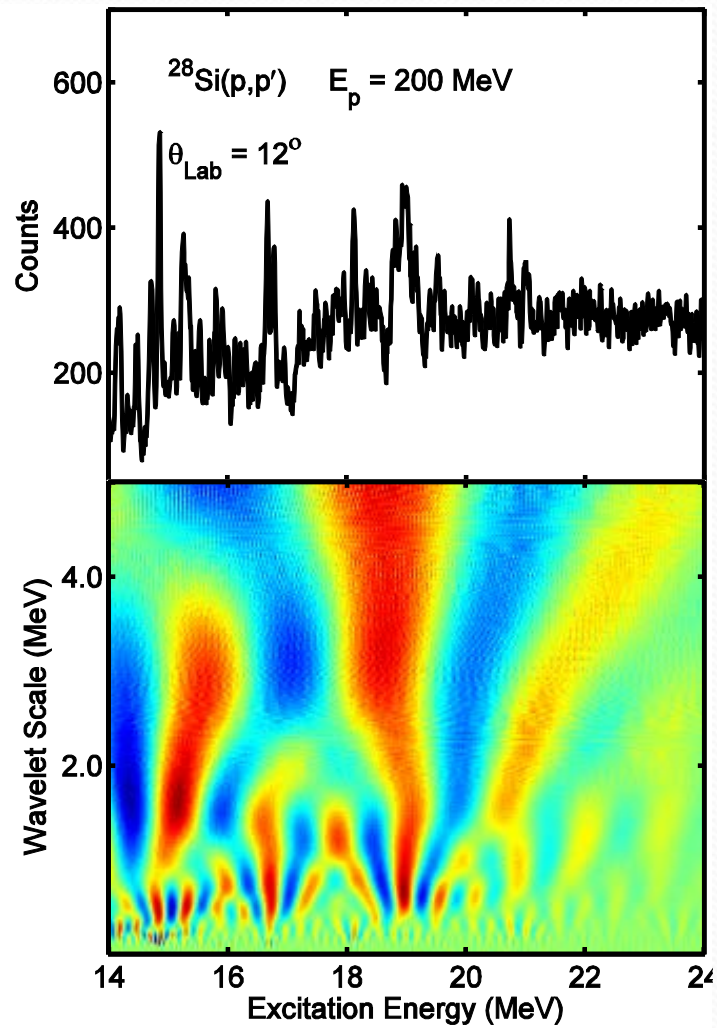
- Complex Lorentzian:

$$\Psi(x) = \sum_{n=-8}^{+8} \frac{(\Gamma/2)^2}{\left(x - (x_o + n f_c)\right)^2 + (\Gamma/2)^2} \exp\left(-\frac{x^2}{2 f_b}\right)$$

Characteristic Energy Scales in ^{28}Si

Power Spectra





Wavelet Coefficient

Comparison with theoretical calculations

- To understand the origin and physical nature of different scales, comparison of experimental results with model calculations is important.

- Such models include
  - Quasi-particle Phonon Model (QPM)
  - Random Phase Approximation (RPA)
  - Second-RPA (SRPA)

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Physics Letters B

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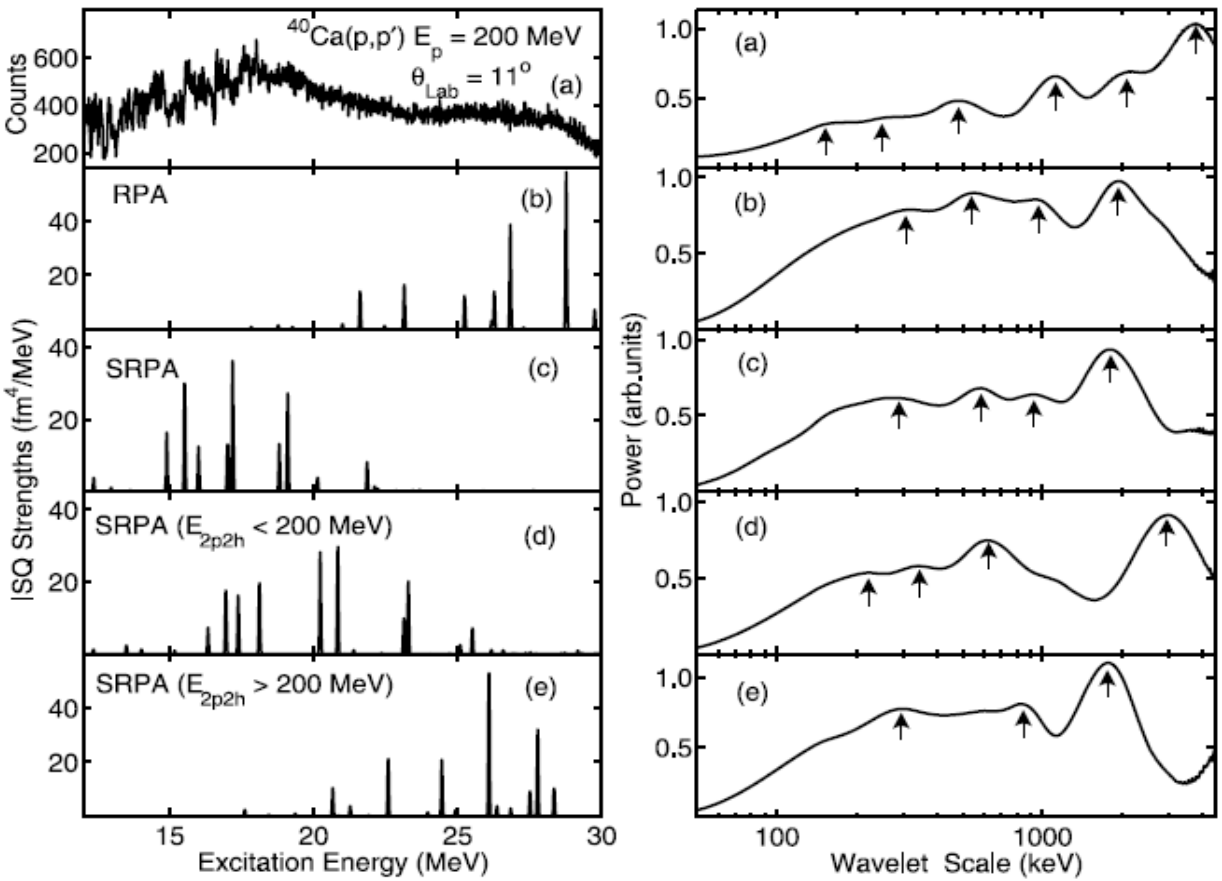
Fine structure of the isoscalar giant quadrupole resonance in ^{40}Ca due to Landau damping?

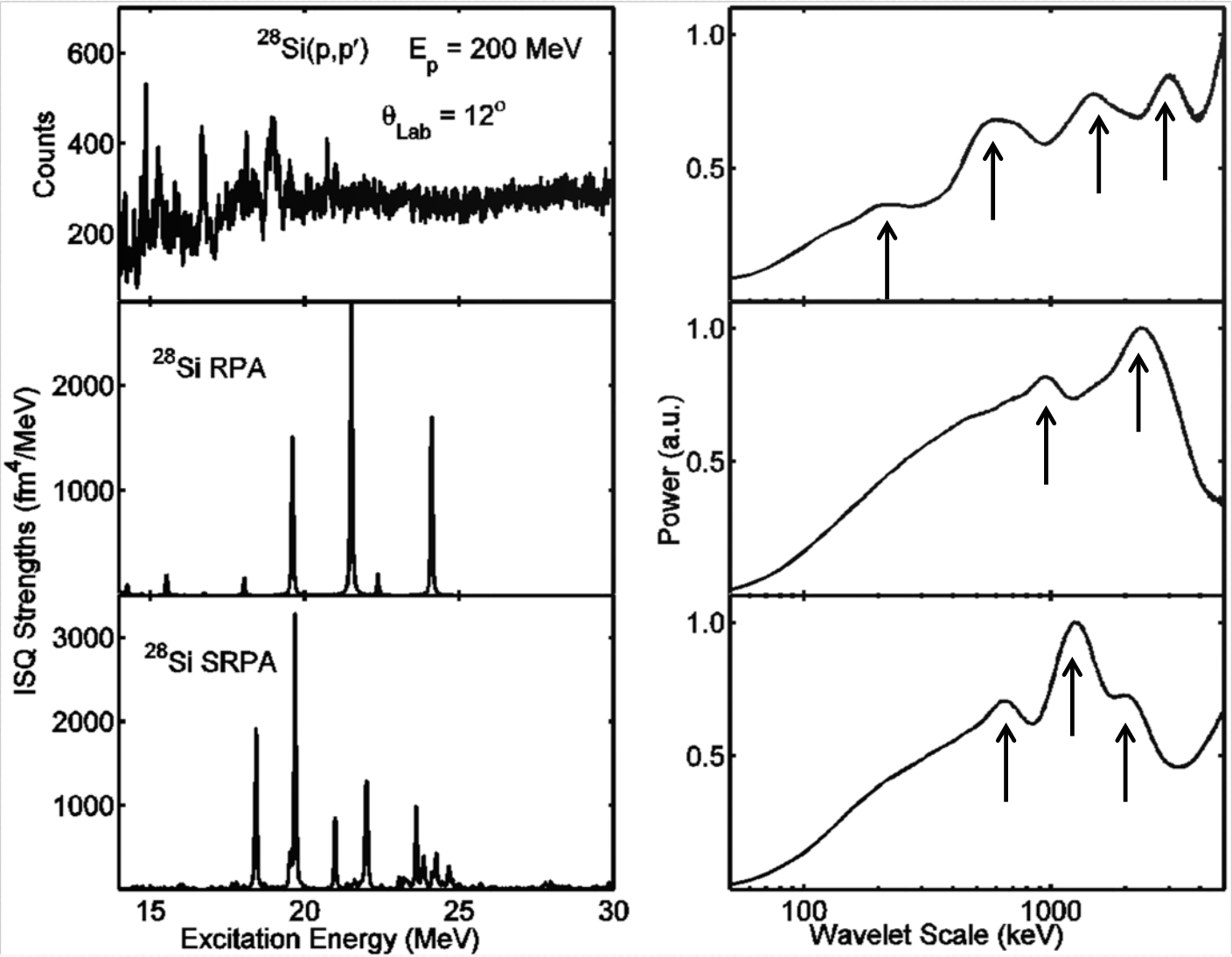
I. Usman [a,b], Z. Buthelezi [a], J. Carter [b], G.R.J. Cooper [c], R.W. Fearick [d], S.V. Förtsch [a], H. Fujita [a,b], Y. Fujita [e], Y. Kalmykov [f], P. von Neumann-Cosel [f,*], R. Neveling [a], P. Papakonstantinou [f], A. Richter [f,g], R. Roth [f], A. Shevchenko [f], E. Sideras-Haddad [b], F.D. Smit [a]



What is the origin of scales in ^{40}Ca?

The RPA model accounts for Landau damping, which plays an important role in the case of ^{40}Ca.

Experimental and Theoretical Energy Scales



Semblance and Dot Product Analysis

- **Wavelet based semblance *S***

$$S = \cos^n(\theta)$$

$$\theta = \tan^{-1}\left(I\left(CWT_{1,2}\right)/R\left(CWT_{1,2}\right)\right)$$

- **Cross-wavelet transform $CWT_{1,2}$**

$$CWT_{1,2} = CWT_1 . CWT_2^*$$

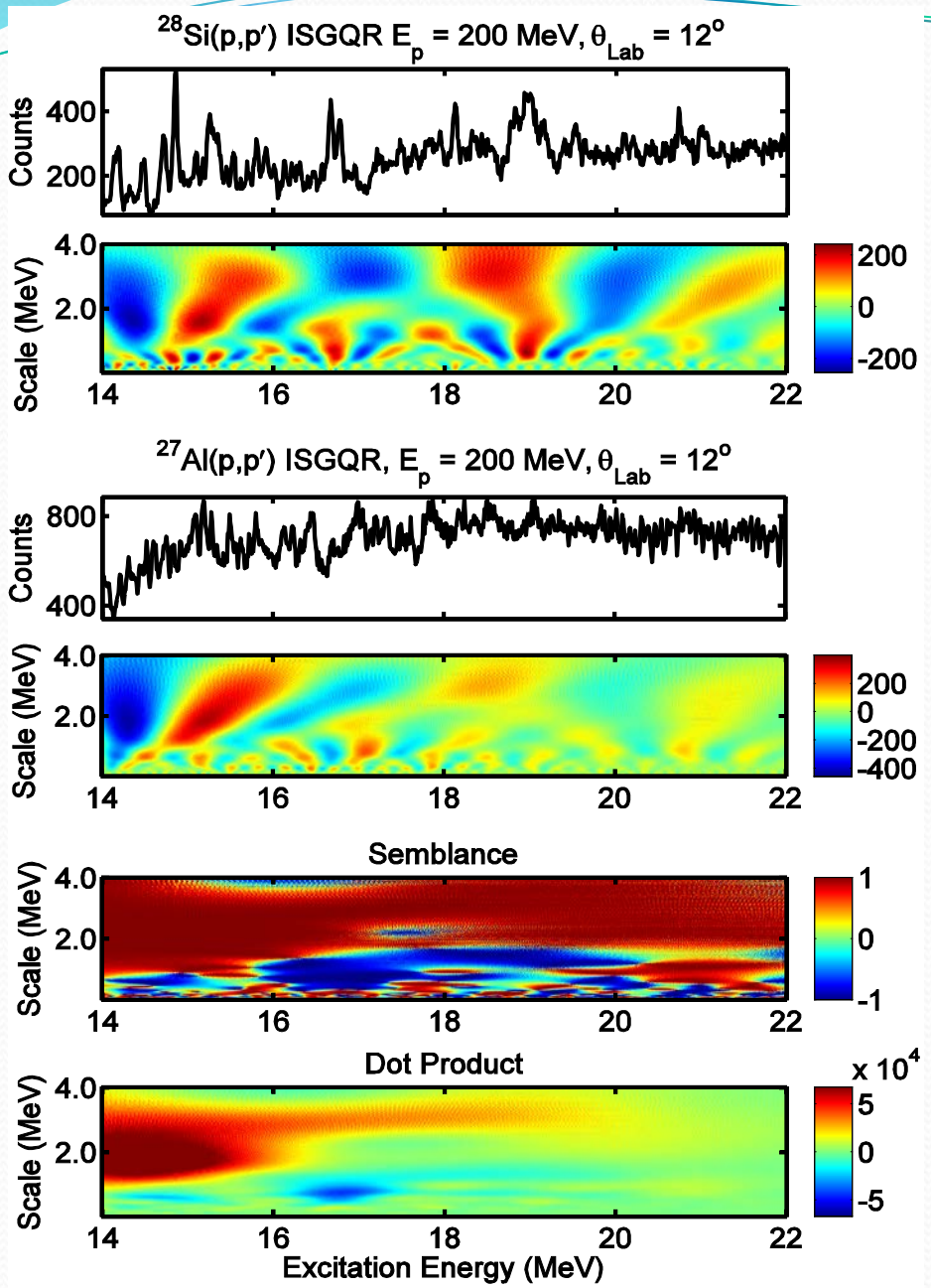
- **Dot-product *D***

$$D = \cos^n(\theta)\left|CWT_{1,2}\right|$$

Where *n* is an odd integer greater than zero,
θ is the local phase which can be range from $-\pi$ and $+\pi$,
$CWT_{1,2}$ is a complex quantity with CWT_1 as the continuous wavelet transform of dataset *1* and CWT_2 as the continuous wavelet transform of dataset *2*.

Ref: G.R.J. Cooper and D. R. Cowan, Computers and Geosciences 34 (2008) 95.

Semblance Analysis of ^{28}Si and $^{27}Al(p,p')$



$^{28}Si(p,p')$

Wavelet Coefficients

$^{27}Al(p,p')$

Wavelet Coefficients

Semblance

Dot product

Summary

- The Fine structure conforms to the suggestion of the global character of this phenomenon in the ISGQR, present in many different nuclei.

- RPA and SRPA calculations do not reveal the energy scales below 300 KeV in ^{28}Si.

- Blue area indicating anti-correlation between the ISGQR regions of ^{28}Si and ^{27}Al. This can be due to the restricted configuration available in the extreme single-particle shell model.

K600 Collaboration

- iThemba LABS

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Thank You