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Single-Particle Structure in Neutron-rich calcium isotopes P-358

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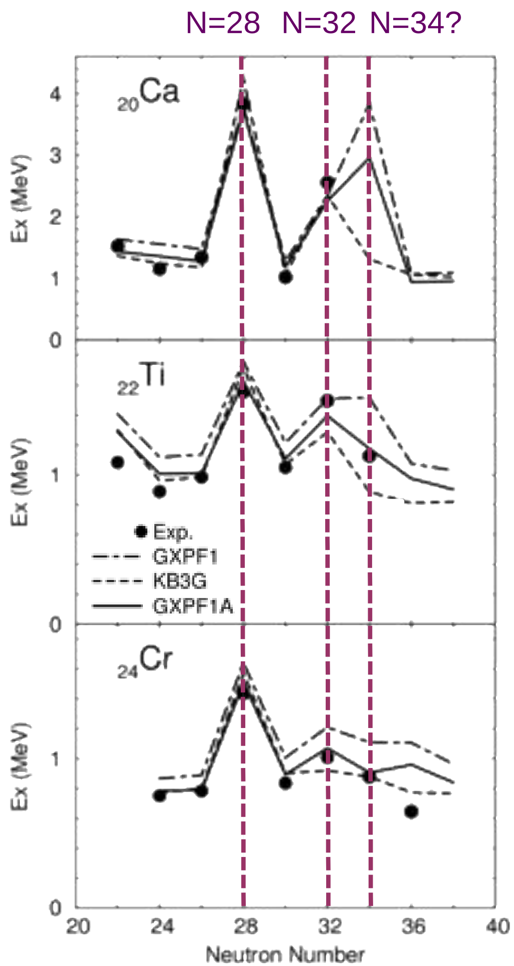
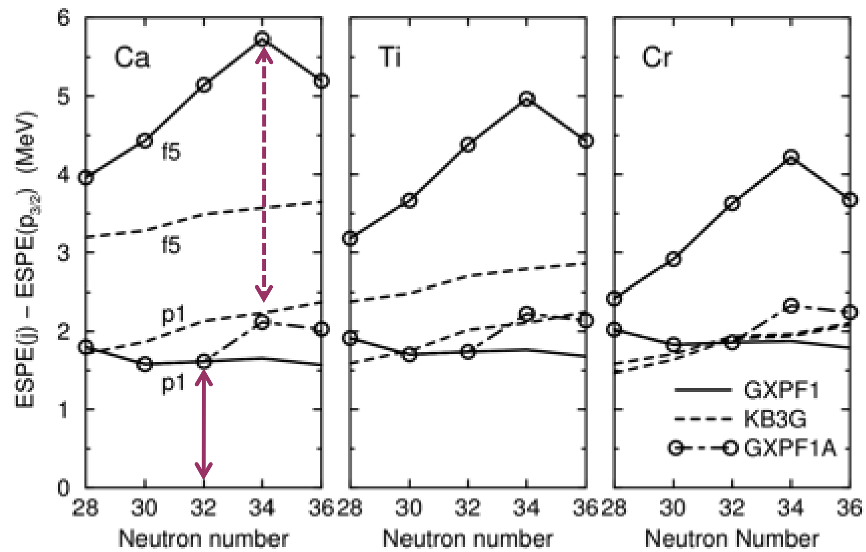
INTC October 2012

2+ Energies



Predicted effective single-particle energies



- Neutron-rich region of the fp shell attracted interest associated with testing shell models, development of collectivity and with shell stability.
- For example, a *N=32* gap in Ca disappears with increasing *Z* due to accumulating attractive effect on $\nu f_{5/2}$ by $\pi f_{7/2}$ closing gap beyond Cr.

Some shell model interactions predict a sizeable N=34 gap due to large $\nu f_{5/2}$-$p_{1/2}$ separation:
•GXPF1A: increases to N=34 due to trends in ESPE.
•KB3G: small and stays roughly constant.

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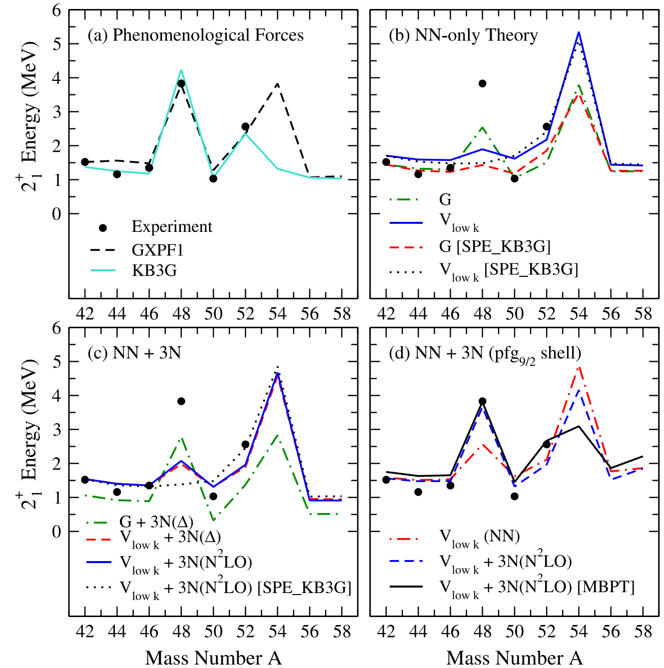
Persists in more microscopic calculations, albeit somewhat weaker than in GXPF1A.



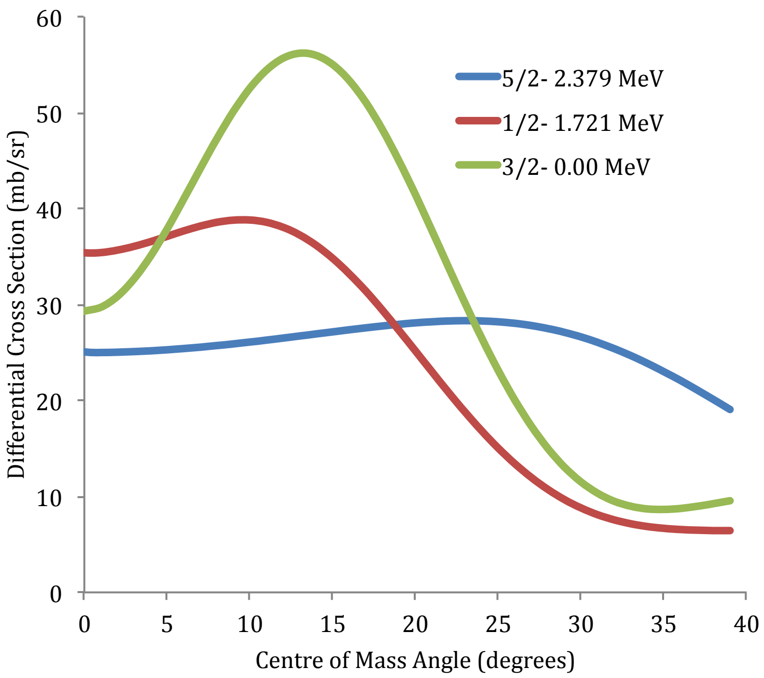
Experimental situation difficult:

- ^{54}Ca direct spectroscopy very hard.
- Other approaches (out as far as ^{52}Ca) lead to ambiguous conclusions; usually only energies and tentative spins.

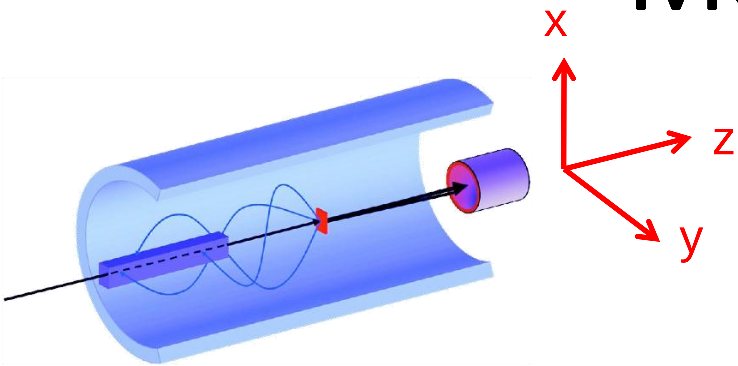
Probe single-particle nature of ground and low-lying states in ^{51}Ca using the (d,p) reaction.

Experiment

- $d(^{50}Ca,p)$ @ 5.5 MeV/u.
- HIE energies give confidence to single-step mechanism.
- Expect at least $4x10^5$ pps at HRS; $>10^4$ on target.
- ^{50}Ti expected beam contaminant.
- Requires good Q-value resolution to disentangle, if beam and contaminant of the same order of magnitude.
- Monitoring of contaminant levels using Si/Bragg detector and passive beam attenuator.



Method: Solenoid

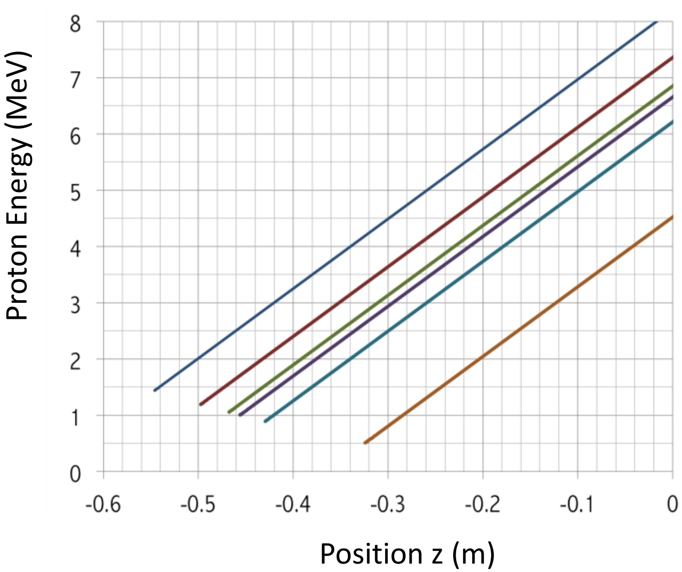


Measure: E_{lab} and z.
T_{cyc} for particle id, less important for (d,p)

$$E_{\rm cm} = E_{\rm lab} + \frac{mV_{\rm cm}^2}{2} - \frac{mzV_{\rm cm}}{T_{\rm cyc}}$$

- Solenoidal field, on-axis Si measure E_{lab} as function of z.
- Linear function, rotate to get E^* spectrum.
- E^* resolution combination of lab E_{lab} resolution (including Si resolution and beam spot size) and contribution from z resolution (small), if beam energy is well defined.
- If target losses significant, limits E_{lab} resolution, but NOT compounded in E^* by compression.

Example: d(^{132}Sn,p)^{133}Sn @ 8 MeV/u 2T



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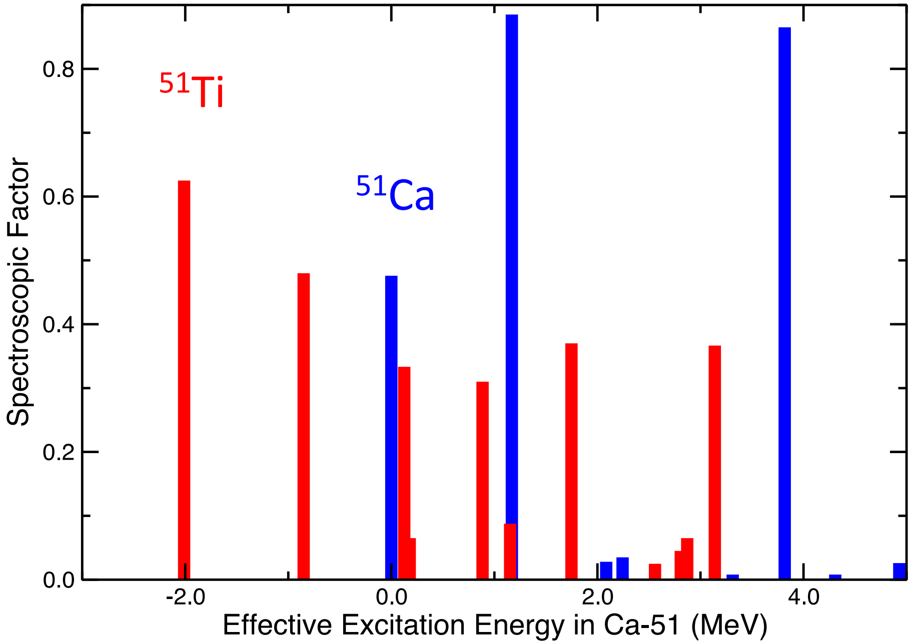
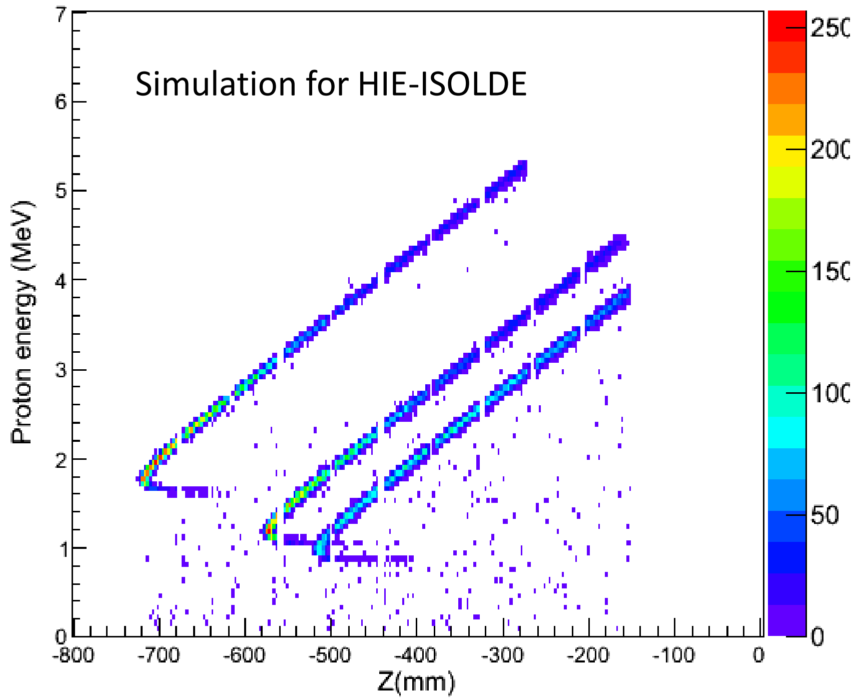
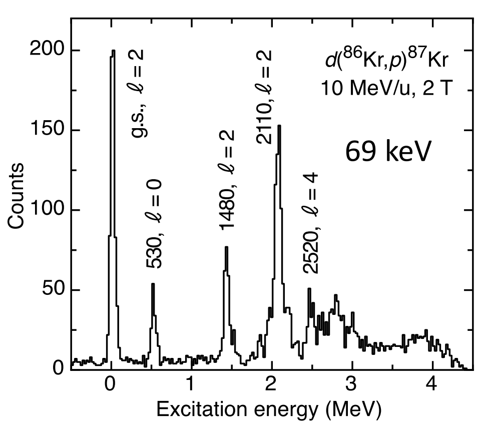
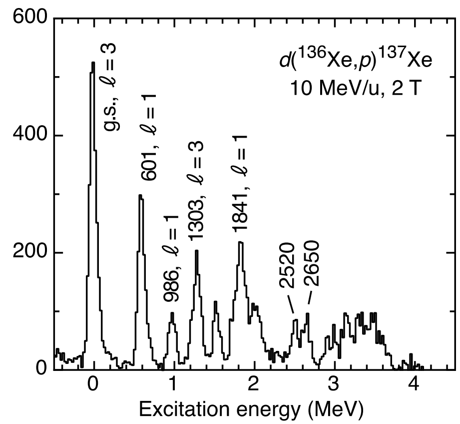
- Requires <120 keV resolution to cope with beam contaminant.
- Requires measurement of ground-state.
- Solenoid will provide ~80keV: simulation with 0.1% energy resolution, 3mm beam spot and 100μg/cm^2 target.
- Similar to expectations based on HELIOS operation at Argonne.
- Estimate in 10 shifts could measure down to a level of C^2S=10%.



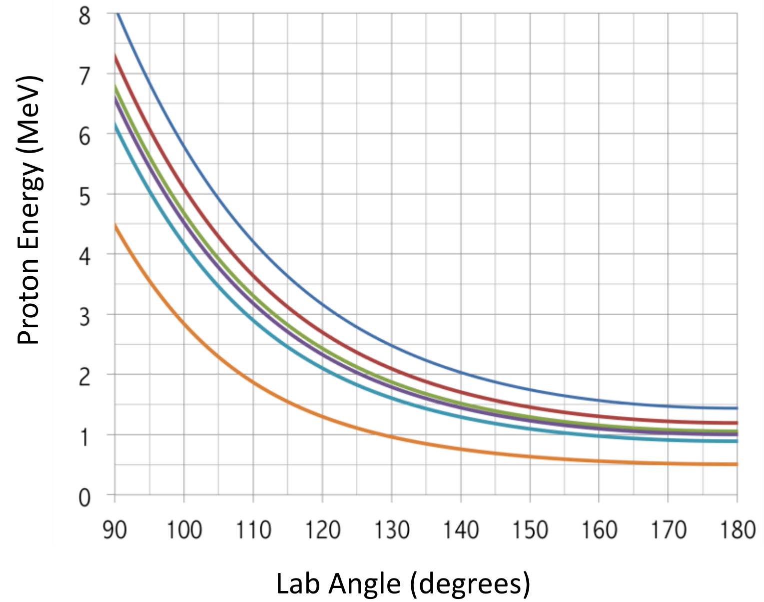






Method: Si array only

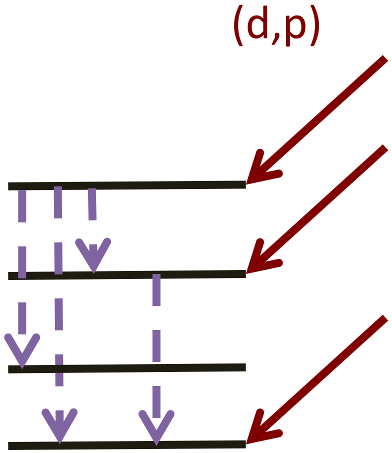
- Traditional Si array: measure E_{lab} as function of ϑ_{lab}.
- Kinematic shift limits E_p resolution by opening angle.
- Transformation LAB (E_{lab}) to CM (E^*) is non-linear. Compression of E_{lab} spectrum to E^* spectrum, compounds effective Q-value resolution.
- If target losses are a significant contribution gives E_{lab} resolution similar to solenoid, compounded in E^* spectrum by compression.



$$\kappa = \frac{1}{p}\frac{\mathrm{d}p}{\mathrm{d}\theta}$$

Method: Si plus gammas

- Traditional Si array: measure E_p as function of ϑ_{lab} *with* γ-ray coincidences.
- Thick target to compensate ε_γ but compromises E_p resolution.
- Very best resolution in E_γ so precise energy levels.
- Need *BR* and ε_γ for absolute yield of coincidences; may or may not be well known or well measured.
- Always need particle spectrum for angular distribution; poor resolution, but may be cleaned by E_γ gate.
- Could use *p*-$\gamma(\vartheta)$ correlation analysis; needs statistics.
- Can't do ground state and difficult with long isomers.



Excellent energy resolution. Usually at mercy of feeding pattern when comes to deducing reaction yield and angular distribution.

Conclusions?

- What Q-value resolution do we really need?

Always cases of close doublets?
Often tens of keV okay: selectivity of reactions often leads to low level density in observed spectrum?
But higher energy regions? Especially with deformation?
Coped near stability with 10-50 keV with traditional magnetic spectrometers?

- What method do we really need?

Flexibility to suit science case, and generate biggest scientific return.
Development of both to find ultimate solution:
e.g. Add Ge to solenoid? TRS in-ring Si array? Solenoid after TRS? etc.

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