Proposal: Beta-delayed neutron spectroscopy of $^{51-54}$Ca

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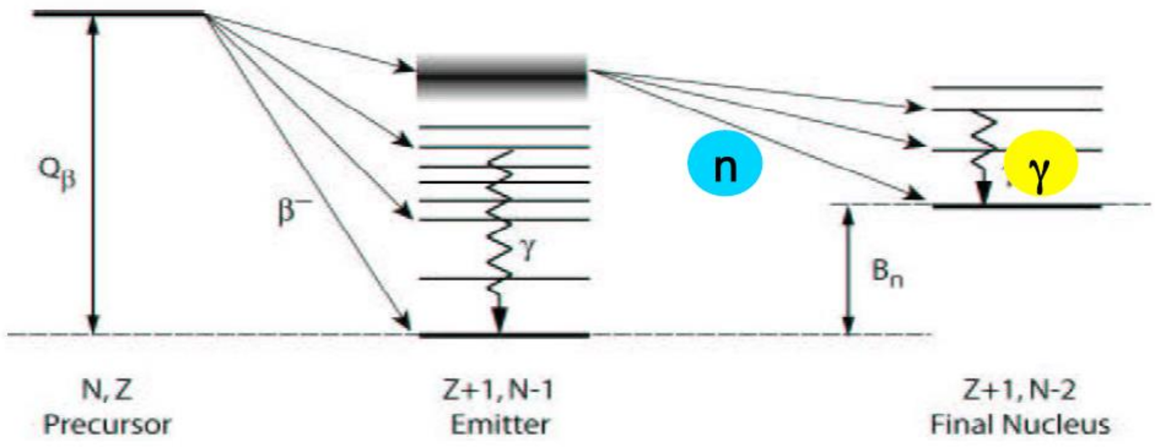
- Why beta-delayed neutron spectroscopy ?
- Spectroscopy of particle-hole states
- GT decays and 2n emission
- The past studies: $^{51-53}$K -> $^{51-53}$Ca
- Perspectives with improved beamtime and new detectors
- Beam-time request

Beta-delayed neutron spectroscopy

In exotic nuclei close to shell closures we can have very large Q values (10 MeV or more)

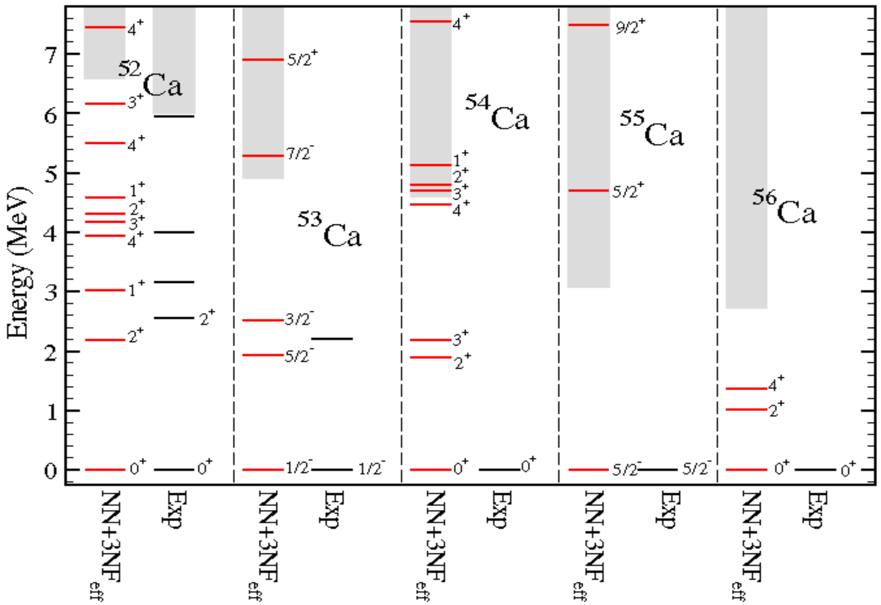


The beta decay can thus populate states below and above the neutron (and 2n) separation threshold

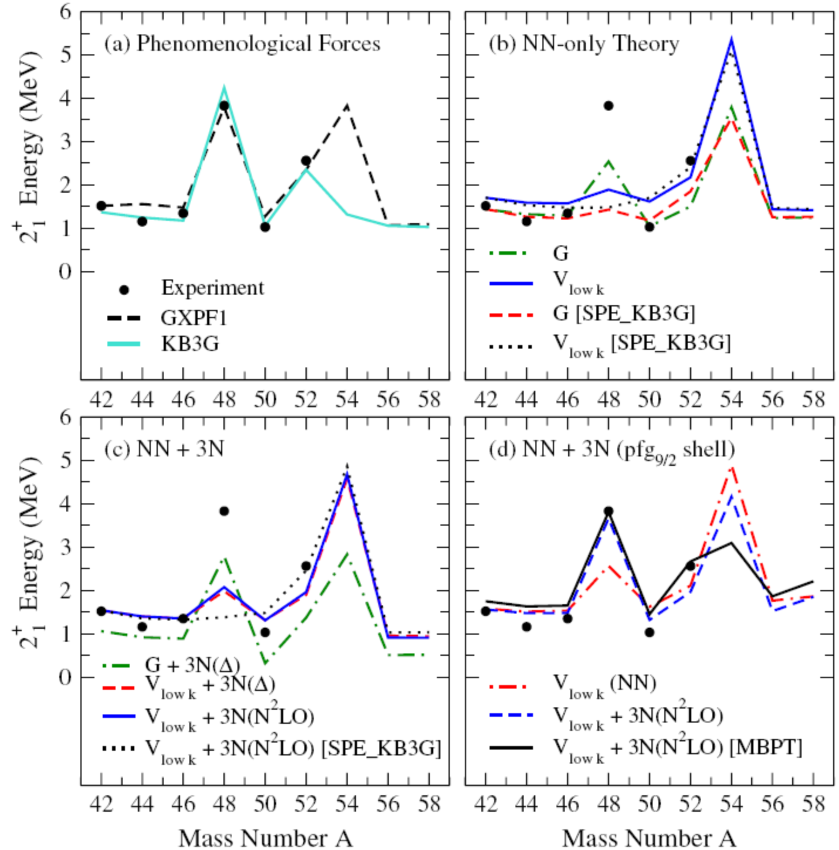
- Where does the beta strenght go through(GT, FF) and to ?
- Particle-hole to measure the shell energies in exotic nuclei

How are the ESPEs evolving ? (1)

Test the evolution of ESPE $\nu f_{7/2}$, $\nu p_{3/2}$, $\nu p_{1/2}$,



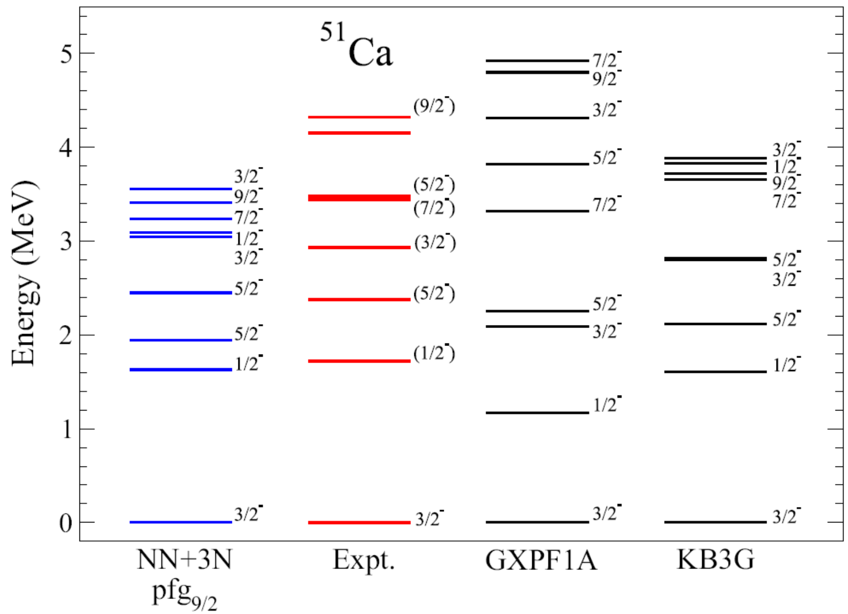
G. Hagen et al., Phys. Rev. Lett. 109, 032502 (2012)

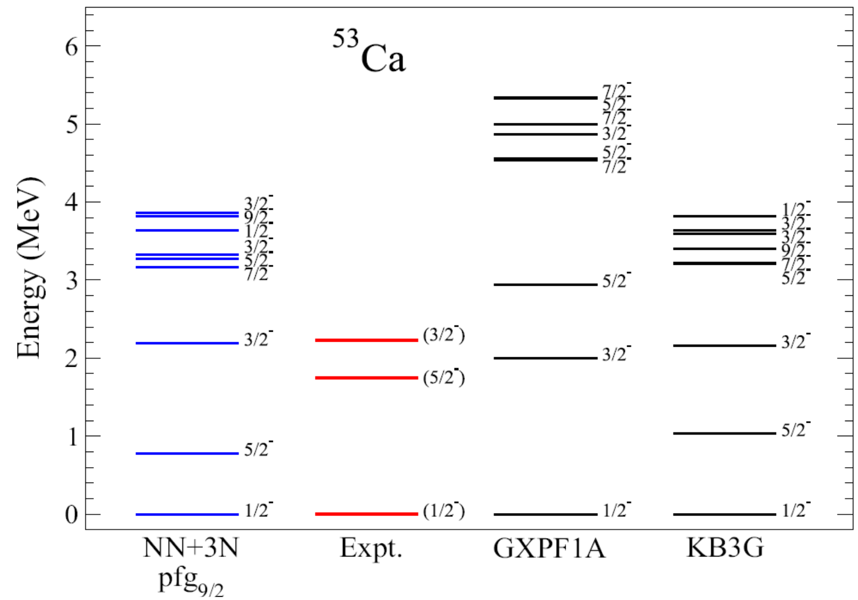


The evolution of ESPEs and gaps in Ca isotopes has been explained in terms of three-body forces.

J. D. Holt et al., J. Phys. G: Nucl. Part. Phys. 39 (2012) 085111

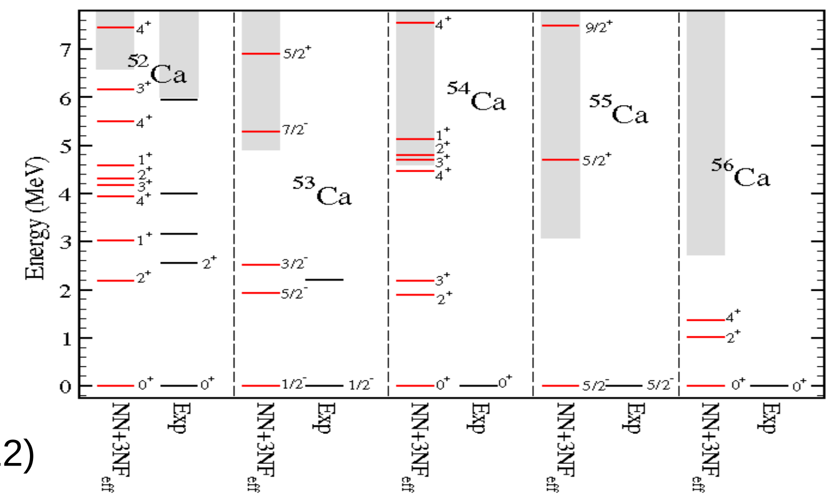
How are the ESPEs evolving ? (2)





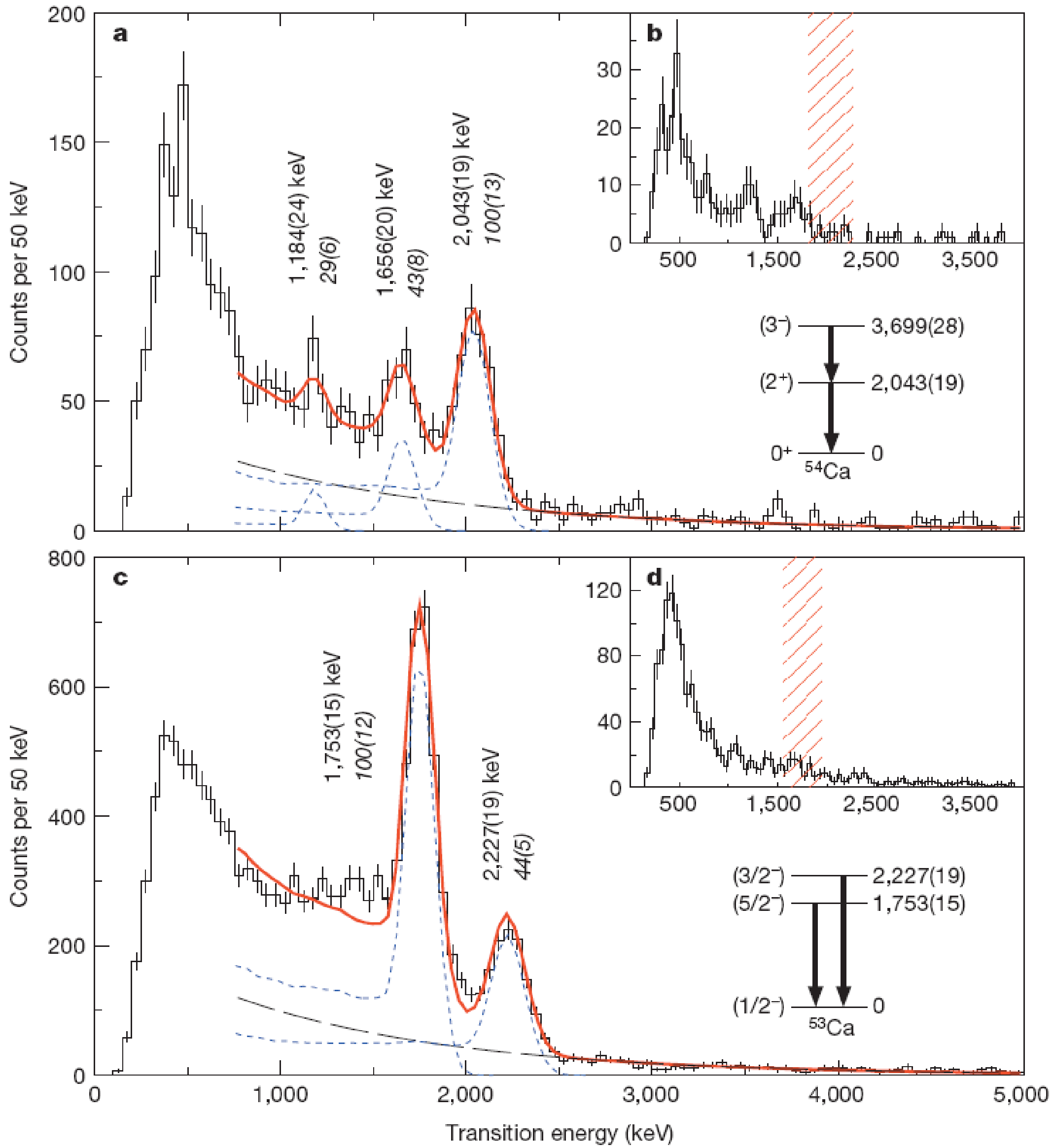
J. D. Holt et al., PRC 90, 024312 (2014)

Different prediction going towards the N=34 for the $f_{7/2}$ gap (different 3N forces + coupling to continuum)



G. Hagen et al., Phys. Rev. Lett. 109, 032502 (2012)

The N=34 closure and ^{53,54}Ca



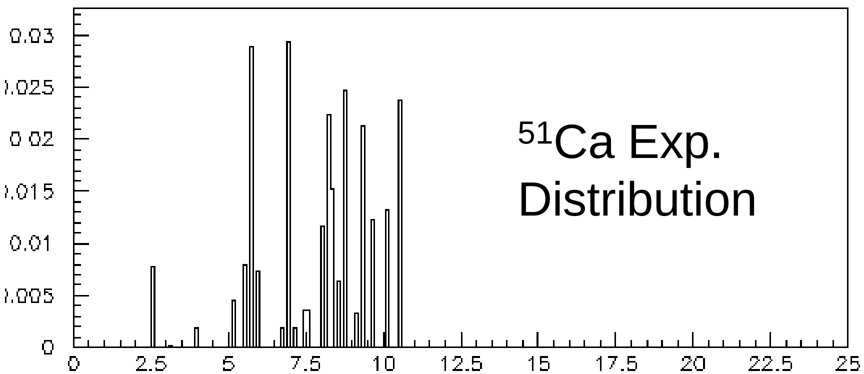
D. Steppenbeck et al., Nature 502, 207 (2013)

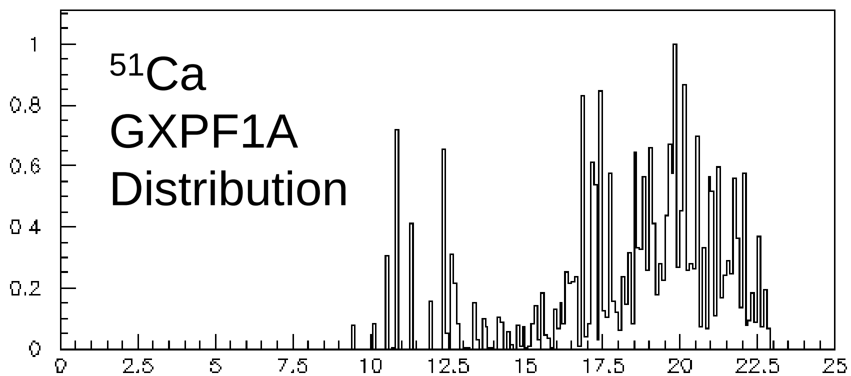
F. Wienholtz et al., Nature 498, 346 (2013)

^{54}Ca : the 2^{+} energy and the mass indicate a subshell closure

^{53}Ca : understanding single-particle energies going towards N=34: $\nu p_{1/2} - \nu f_{5/2}$ gap

GT decay and 2n emission (1)





Energy (MeV)

Courtesy of R. Grzywacz

GT strength distribution: exp. Matrix elements are much smaller than predicted by theory:

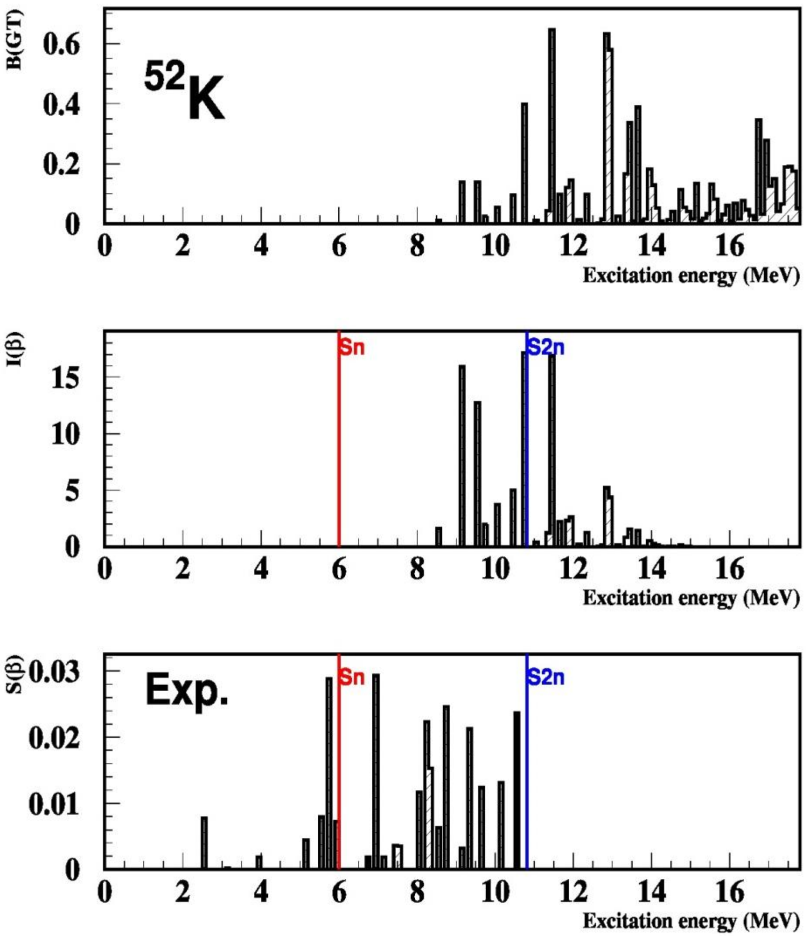
GT strength was probably partially missed because it is going through 2n emission

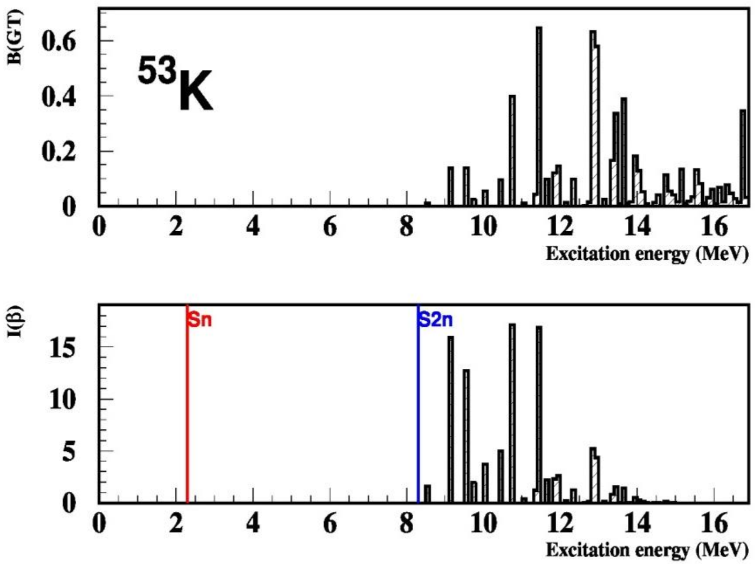
With VANDLE we hope to see the 2n emission in ^{51}Ca,$^{52-53}$Ca and identify the GT strength

Shell-model calculation with chiral 3-body forces have already shown the presence of a 2-body GT operator: different renormalization of the GT strength

J. Menendez et al., PRL 107, 062501 (2011)

GT decay and 2n emission (2)



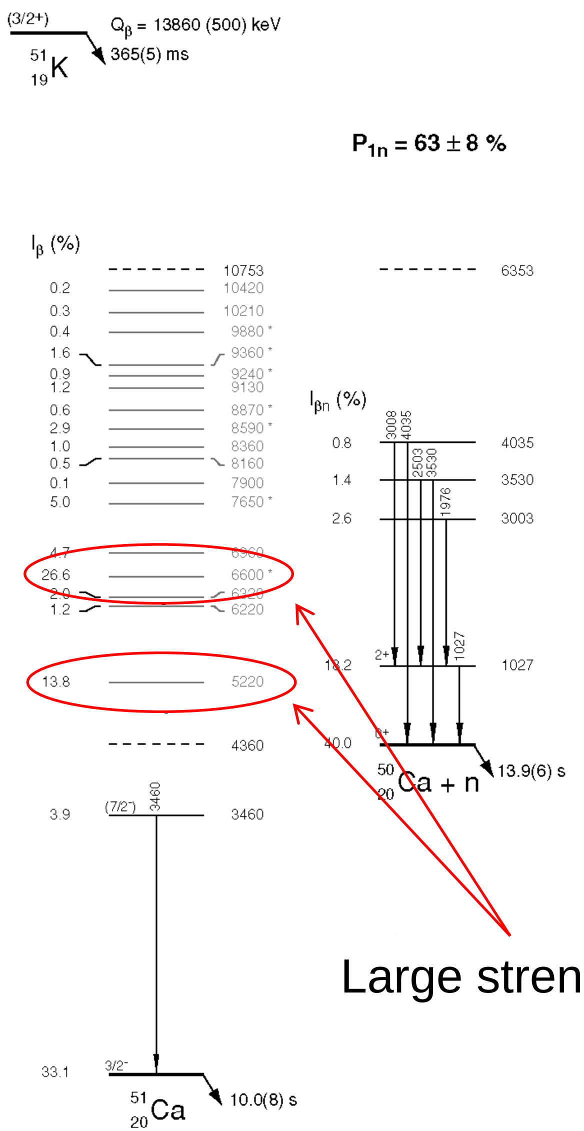


The lowering of the 2n threshold in ^{53}K should make the GT almost all go through 2n emission: need to measure 2 neutrons.

FF should go through 1n or γ emission

Courtesy of R. Grzywacz

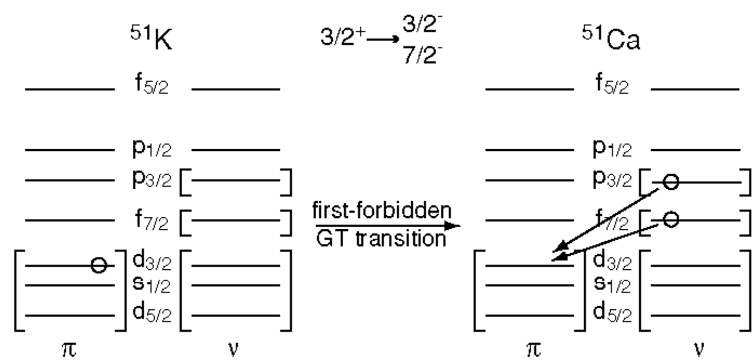
Past ^{51}Ca measurement



Large strength: ?

^{51}Ca : many intersting states above the neutron separation threshold

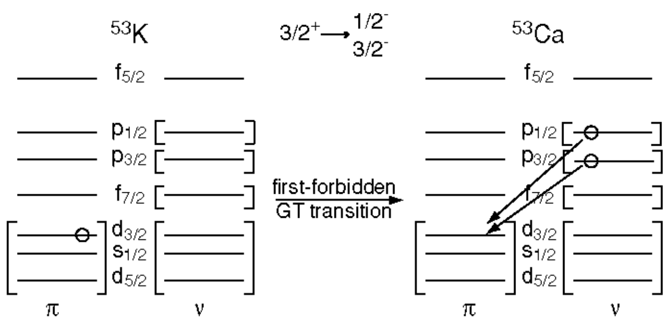
F. Perrot et al., Phys. Rev. C 74, 014313 (2006)



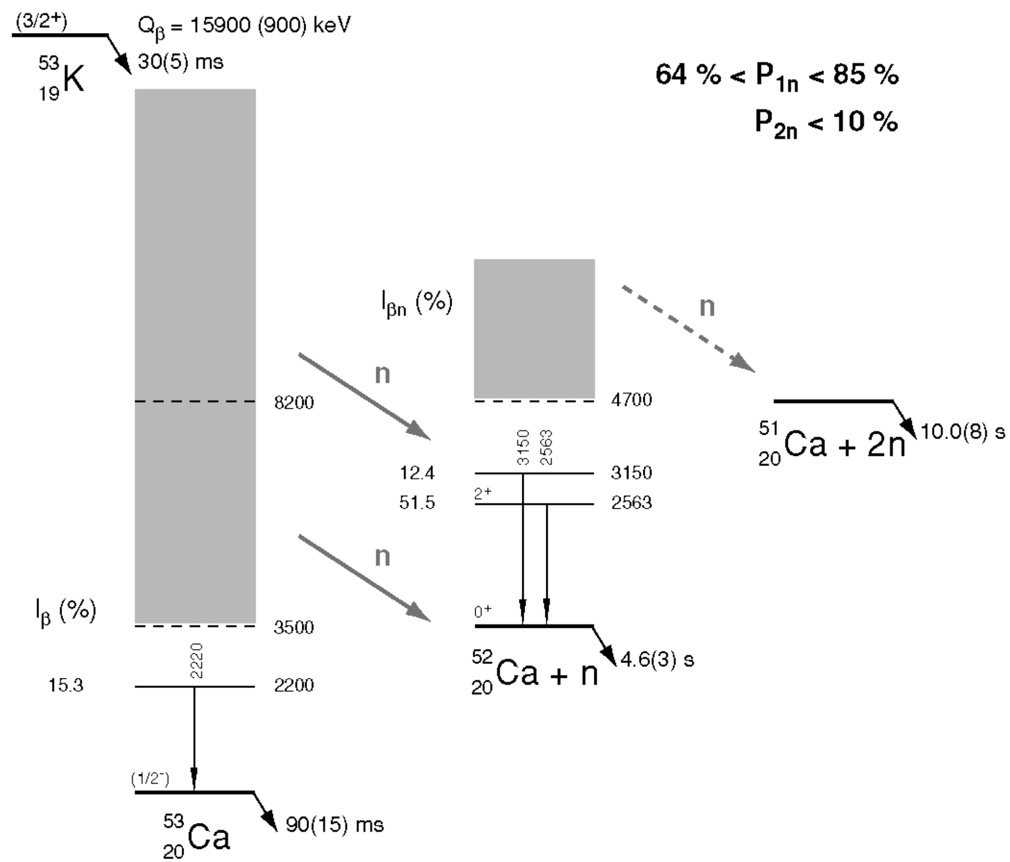
The $7/2^-$ state is an hole in the $\nu f_{7/2}$ shell (FF transition);

GT : $\nu f_{7/2}$ -> $\pi f_{7/2}$ (high energy!)

Past ^{53}Ca measurement



- The GT decay should populate the $\pi f_{7/2}$ shell -> we expect $\nu f_{7/2}^{-1}\ \pi f_{7/2}^{1}$ states at 8-10 MeV: 2n emission
- FF could also lead to $\nu p_{1/2}^{-1}\ \nu p_{3/2}^{-1}\ \nu f_{7/2}^{-1}$ states (closed Z=20)

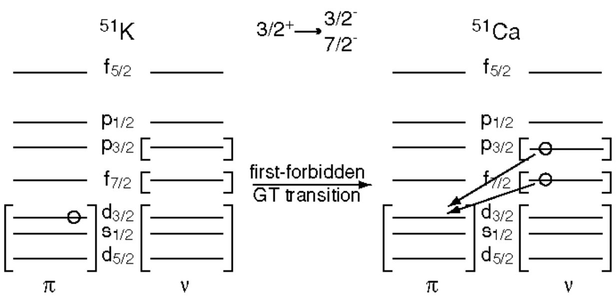


F. Perrot et al., Phys. Rev. C 74, 014313 (2006)

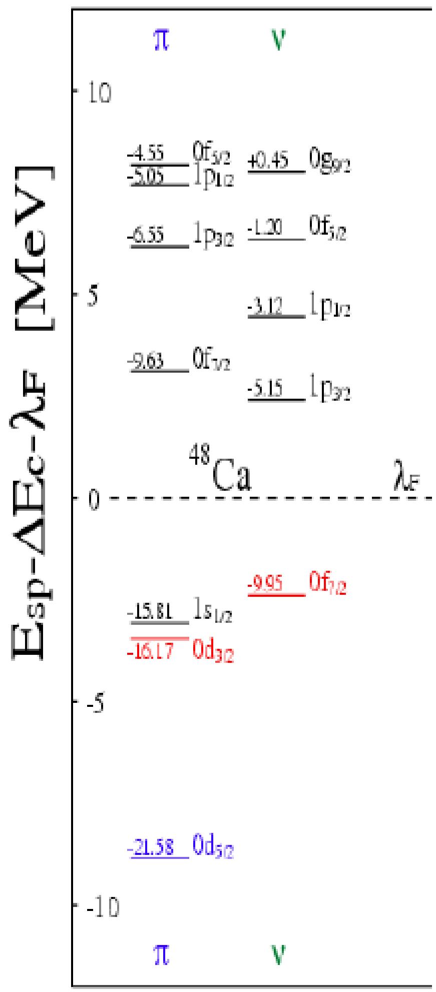
Not enough statistics to reconstruct the level scheme

What we want to measure

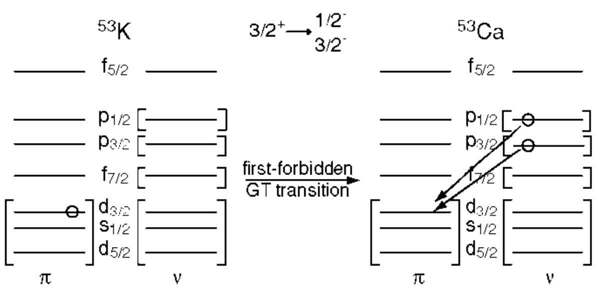
^{51}Ca



- The GT decay should populate the $\pi f_{7/2}$ shell -> we expect $\nu f_{7/2}^{-1}\ \pi f_{7/2}^{1}$ states at 8-10 MeV: 2n emission
- FF also lead to $\nu p_{3/2}^{-1}\ \nu f_{7/2}^{-1}$ states (closed Z=20)



^{53}Ca



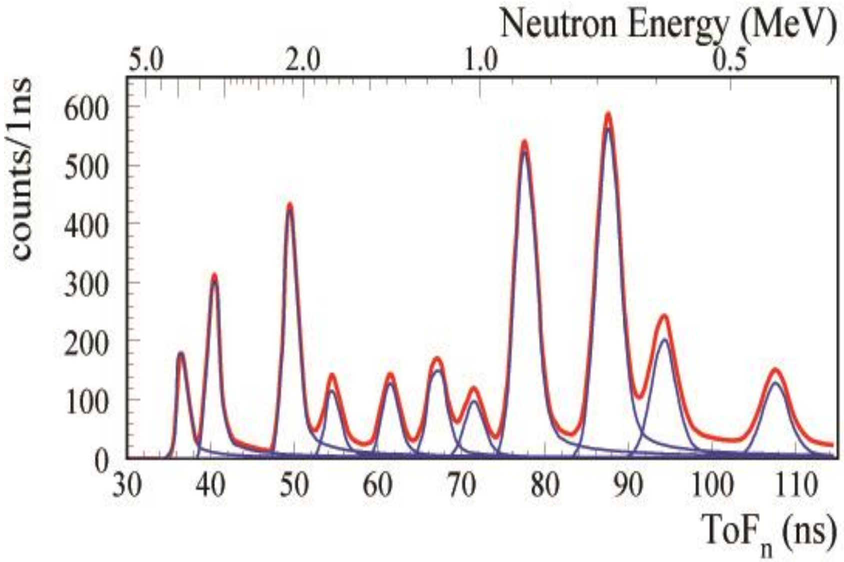
- The GT decay should populate the $\pi f_{7/2}$ shell -> we expect $\nu f_{7/2}^{-1}\ \pi f_{7/2}^{1}$ states at and above 10 MeV: 2n emission
- FF could also lead to $\nu p_{1/2}^{-1}\ \nu p_{3/2}^{-1}\ \nu f_{7/2}^{-1}$ states (closed Z=20)

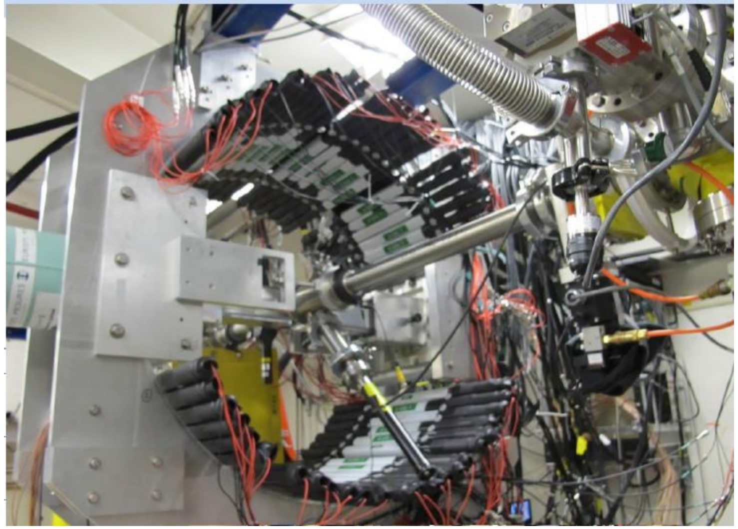
^{51,52,53}Ca: GT and FF strength distribution

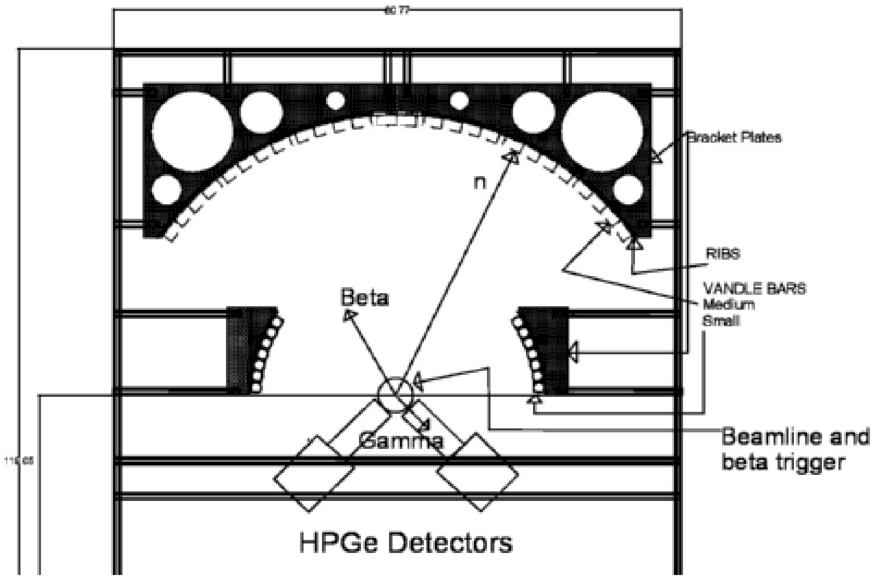
Experimental setup: VANDLE + IDS

VANDLE neutron array

ε: 10 %; σ: 80 keV (1 MeV)







Experimental setup: rates

1n efficiency	2n efficiency	γ efficiency
10 %	~ 0.1 %	~ 2 %

	^{51}K	^{52}K	^{53}K
Production rates	32000 pps	3000 pps	50 pps
Counts (1n)	$5.67 \cdot 10^7$	$1.35 \cdot 10^7$	$5 \cdot 10^5$
Counts (2n)	?	$3.2 \cdot 10^4$	$7 \cdot 10^3$

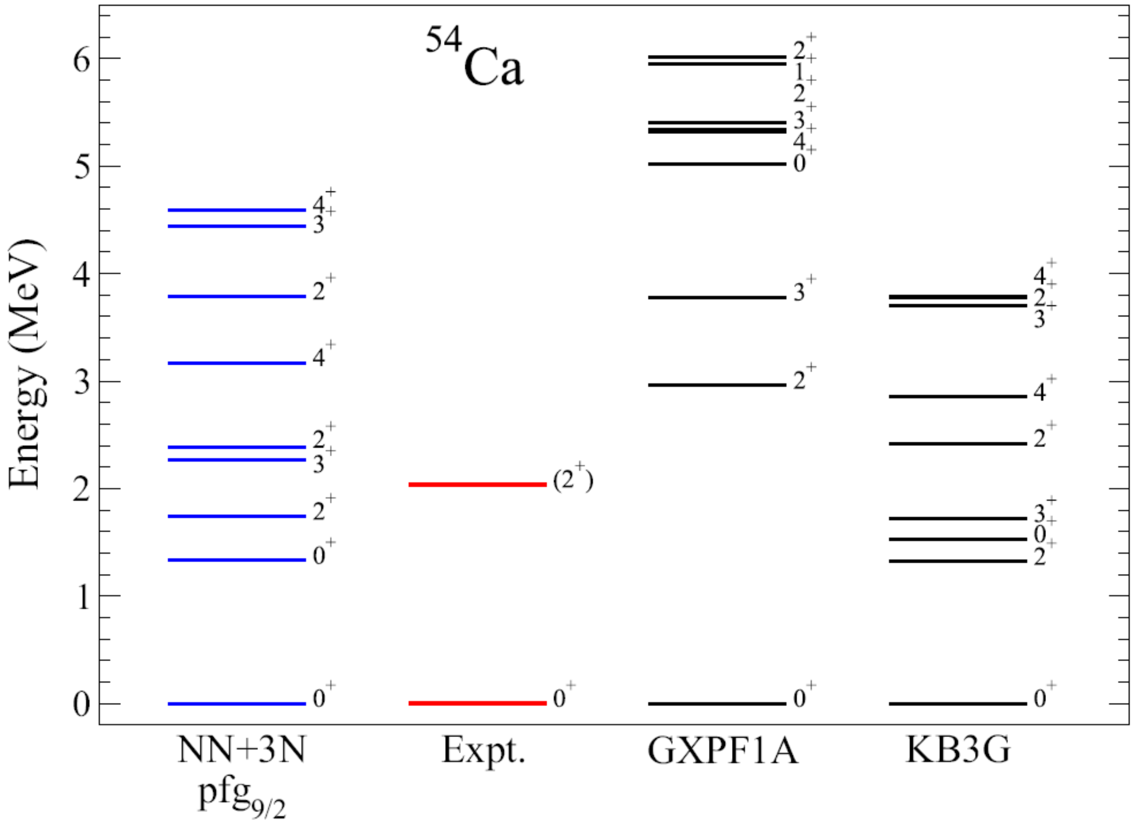
Beam-time request summary

In total, 22 shifts (seven days) are requested

	^{51}K	^{52}K	^{53}K	^{54}K
Beam time (shifts)	**3**	**4**	**12**	**3**

^{54}K -> ^{54}Ca: worth a try !

Challange: producion rate never really observed: ≤ 1 pps. We suppose only 10% population of the bound excited states (2^+)



	^{54}K
Production rate	1 pps
Counts γ (10 % population)	30

Collaboration

A. Gottardo[1], R. Grzywacz[2], M. Madurga[3],
G. de Angelis[4], F. Azaiez[1], D. Bazzacco[5], G. Benzoni[6], A. Boso[5], Y. Deyan[1], M.-C.Delattre[1], P. Van Duppen[7], A. Etilé[8], S. Franchoo[1], C. Gaulard[8], G. Georgiev[8], S. Go[2], A. Goasduff[4], F. Gramegna[4],K. Kolos[2], M. Kowalska[3], S. Ilyushkin[9], G. Jaworski[4], Y. Xiao[2], S.M. Lenzi[5], J. Ljungvall[7], P.R. John[5], R. Li[1], S. Lunardi[5], T. Marchi[4], I. Matea[1], D.Mengoni[5], V. Modamio[4], A.I. Morales[6], P. Morfouace[1], D.R. Napoli[4], S. Paulauskas[10], E.Rapisarda[3], S. Roccia[8], B. Roussier[1], C. Sotty[7], I. Stefan[1] , S. Taylor[2], J.J. Valiente-Dobón[4], D. Verney[1] , H. de Witte[7], A. Algora[11], K. Riisager[12], A. Negret[13], N. Marginean[13], R. Lica[13], C. Mihai[13], R.E. Mihai[13], R. Marginean[13], C. Costache[13], S. Nae[13], A. Turturica[13].

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