Neutron-proton pairing in self-conjugate unstable nuclei through transfer reactions

- np pairing in nuclei
- *fp* shell nuclei & effect of spin orbit
- Experimental set-up
- $^{56}Ni(p,d)$: one-nucleon transfer
- $^{56}Ni, ^{54}Co$ $(p,^{3}He)$: preliminary results

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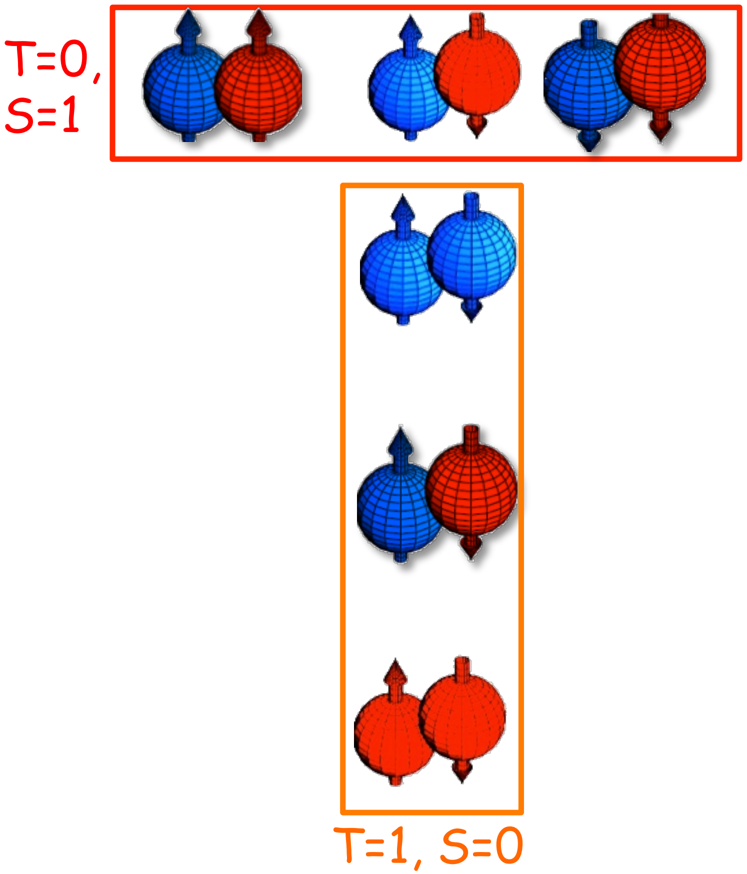
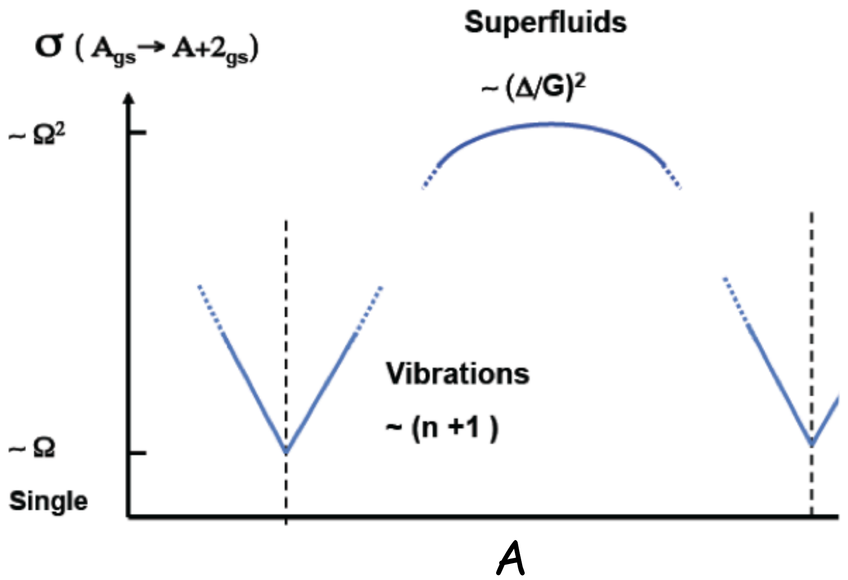
Generalities about np pairing



- np pairing :
  - isovector -> defined from isospin symmetry
  - isoscalar -> a lot of uncertainties !
- np pairing mostly (only) in N=Z nuclei
- d only bound (J=1+,T=0) A=2 nuclei
  T=0 pairing stronger than T=1 ?
- Correlated state // pair phase of superfluid for T=0?
  --> collective modes ?



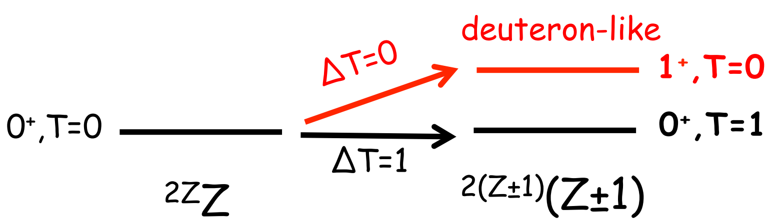
Frauendorf, Macchiavelli, Prog. in Part. Nucl Phys. (2014)

Probing isoscalar pairing through transfer reactions

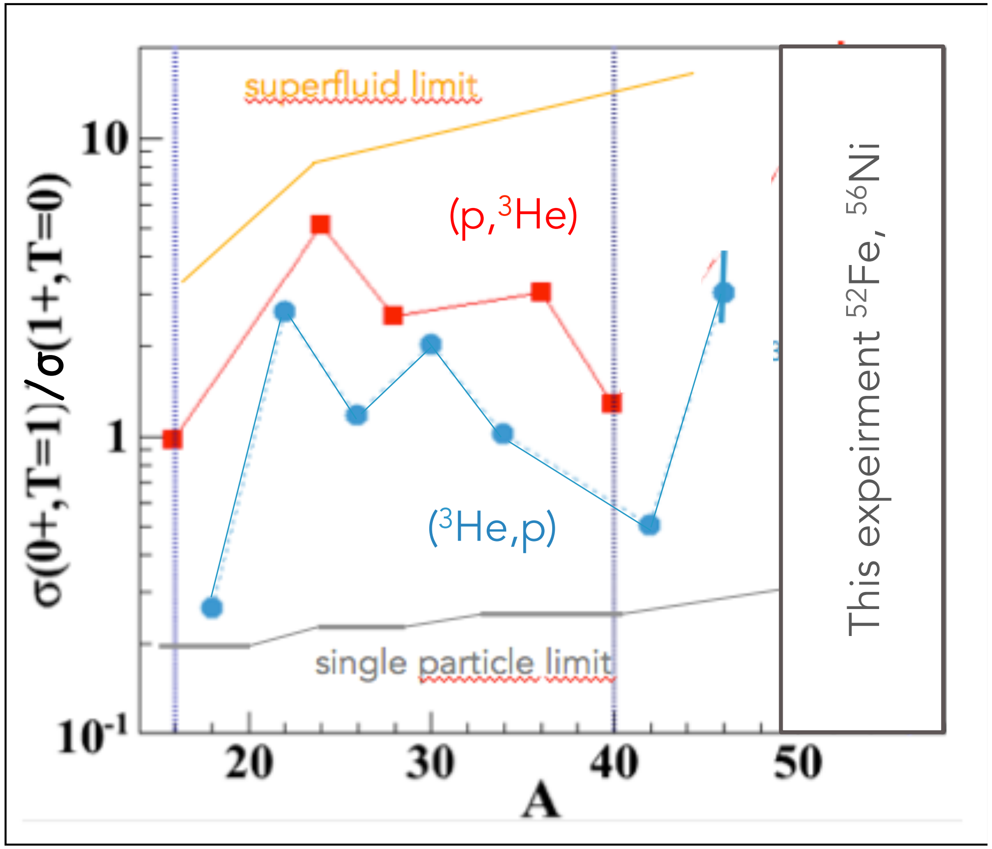
Deuteron-transfer intensities (IBM model)

Reaction	$C^2_{T=0}$	$C^2_{T=1}$
$EE \rightarrow OO_{T=0}$	3	0
$EE \rightarrow OO_{T=1}$	0	$N_b + 3$
$OO_{T=1} \rightarrow EE$	0	$N_b + 1$

P. van Isäcker, PRL (2005)



- Transfer is proportionnal to the number of pairs
- σ (0⁺)/σ (1⁺)= gives the relative strength of T=0/T=1 pairing



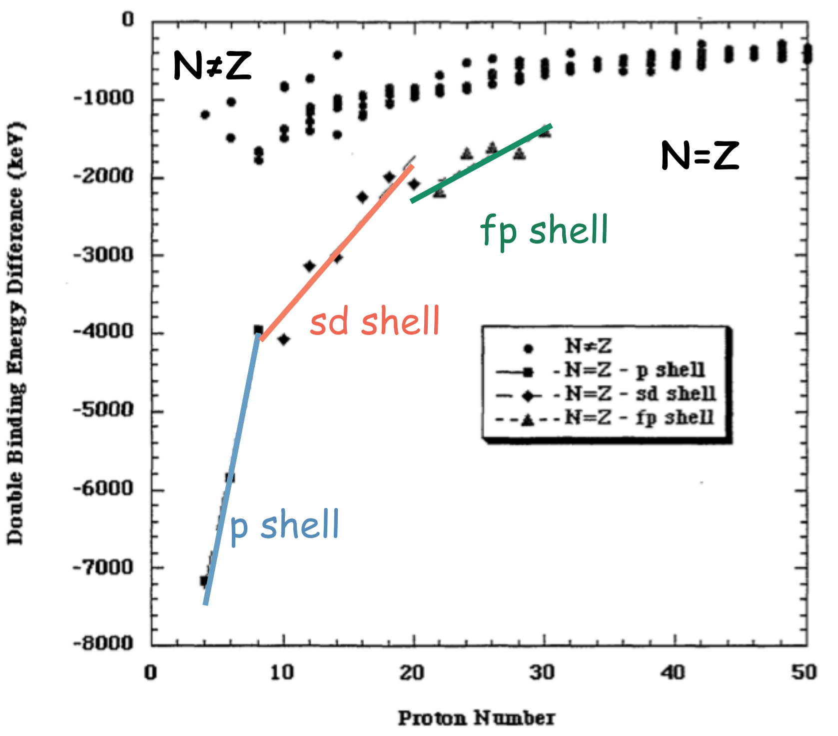
Experimental status

- sd shell systematic
  (remeasured see Y. Ayyad-Limonge)
- One measurement in fp shell : ^{44}Ti
  A.O. Macchiavelli to be published

Shell effects on np pairing

▶ Binding Energies

adapted from O. Juillet



▶ Theoretical predictions

		T=1	T=0	overlap
		$\langle QM\|iv\rangle$	$\langle QM\|is\rangle$	$\langle iv\|is\rangle$
sd shell	^{20}Ne	0.884	0.953	0.843
	^{24}Mg	0.650	0.911	0.336
	^{28}Si	0.590	0.911	0.343
	^{32}S	0.638	0.973	0.595
fp shell	^{44}Ti	0.901	0.678	0.303
	^{48}Cr	0.906	0.497	0.221
	^{52}Fe	0.927	0.753	0.746
	^{104}Te	0.978	0.489	0.314
	^{108}Xe	0.958	0.354	0.234
	^{112}Ba	0.939	0.375	0.376

Quartet model : Sambatoro, Sandulescu PRC (2015)
Shell model : Gezerlis et al, PRL (2011)

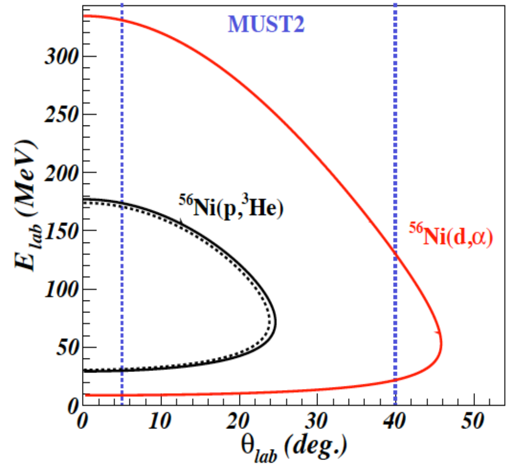
- ✧ isoscalar pairing affected by shell effects
- ✧ spin-orbit effect on np pairing particularly in fp shell)

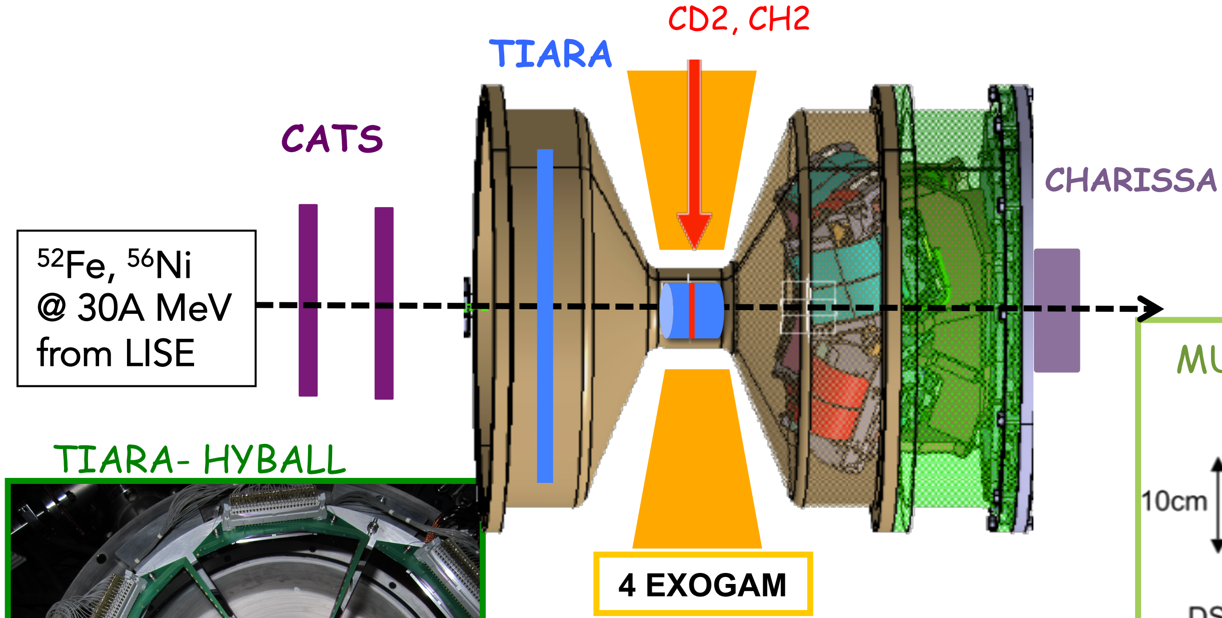
▶ Further measurements in fp shell : ^{56}Ni, ^{52}Fe

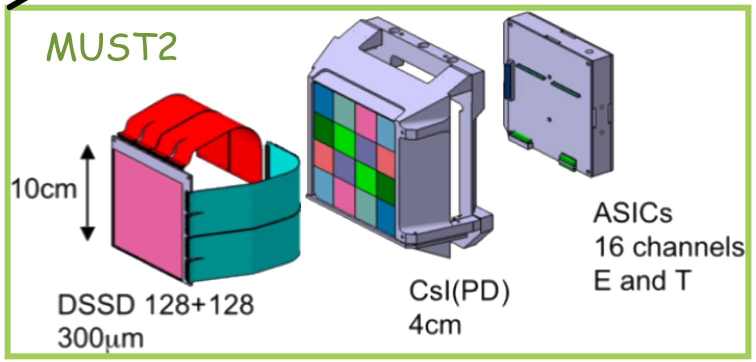
Experimental set-up

$^{56}Ni(p,^{3}He)^{54}Co$ & $^{52}Fe(p,^{3}He)^{50}Mn$

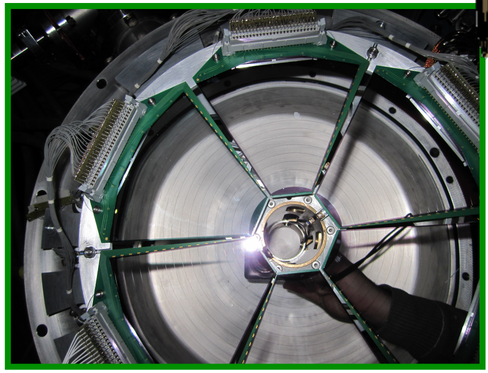
thick target CH_2 : 7 mg/cm^2
beam energy : 30A MeV



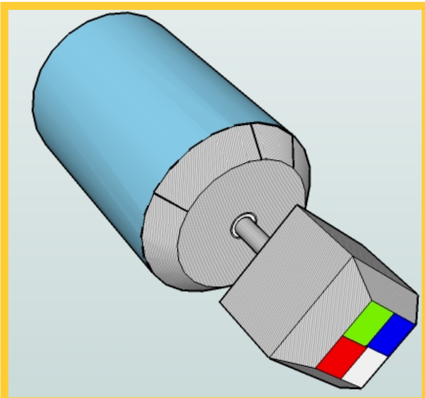




TIARA- HYBALL



Efficiency ~8%@ 1 MeV
Energy resolution 3 keV
Doppler broadening 80 keV



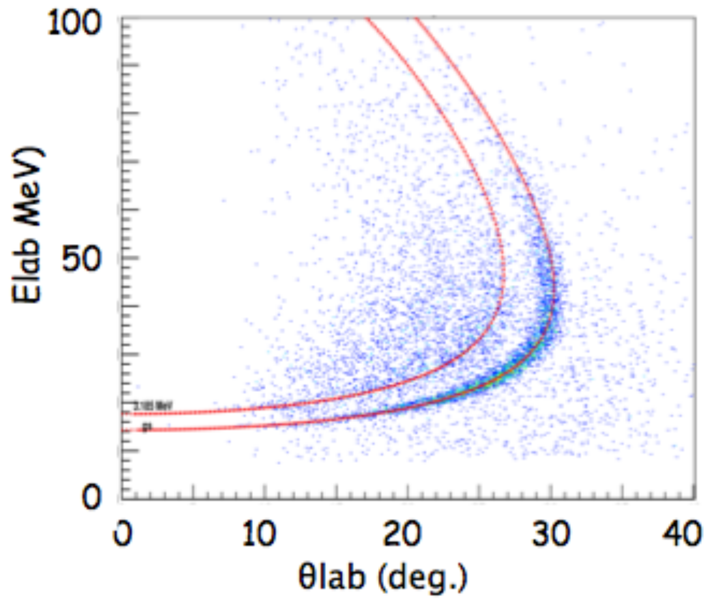
- 1821 keV, 3+, T=0
- 1445 keV, 2+, T=1
- 936 keV, 1+, T=0
- 197keV (isomeric)
- 0+, T=1

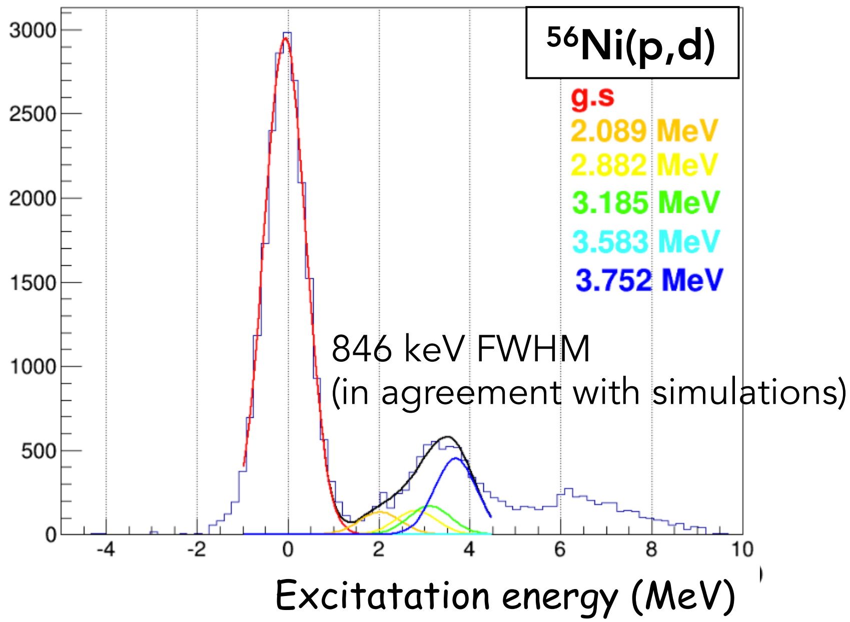
^{54}Co

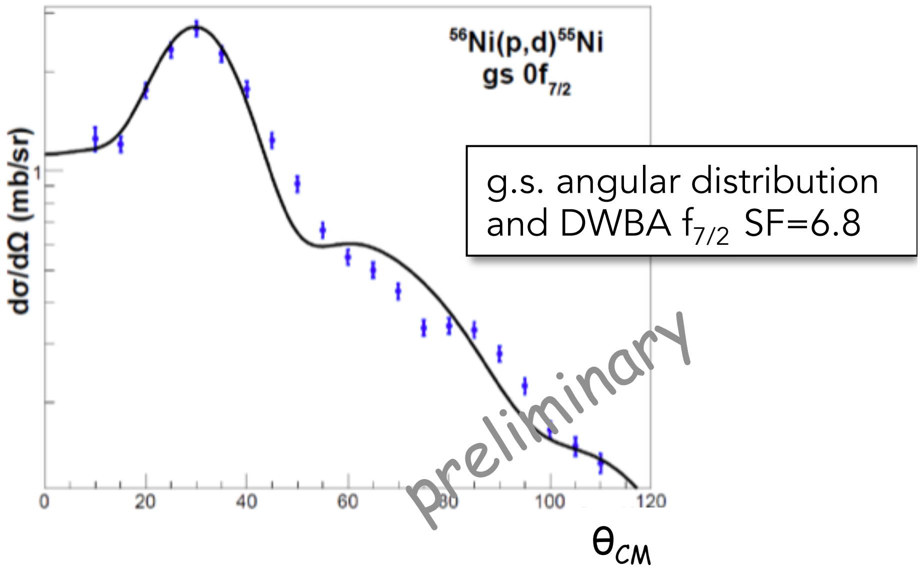
^{56}Ni(p,d) reaction as calibration

^{56}Ni(p,d)^{57}Ni for calibration

- already measured (Sanetullaev et al, PLB 2014)
- energy calibration of MUST2
- alignement of CATS-MUST2
- resolution = 846 keV (FWHM) as expected from simulations

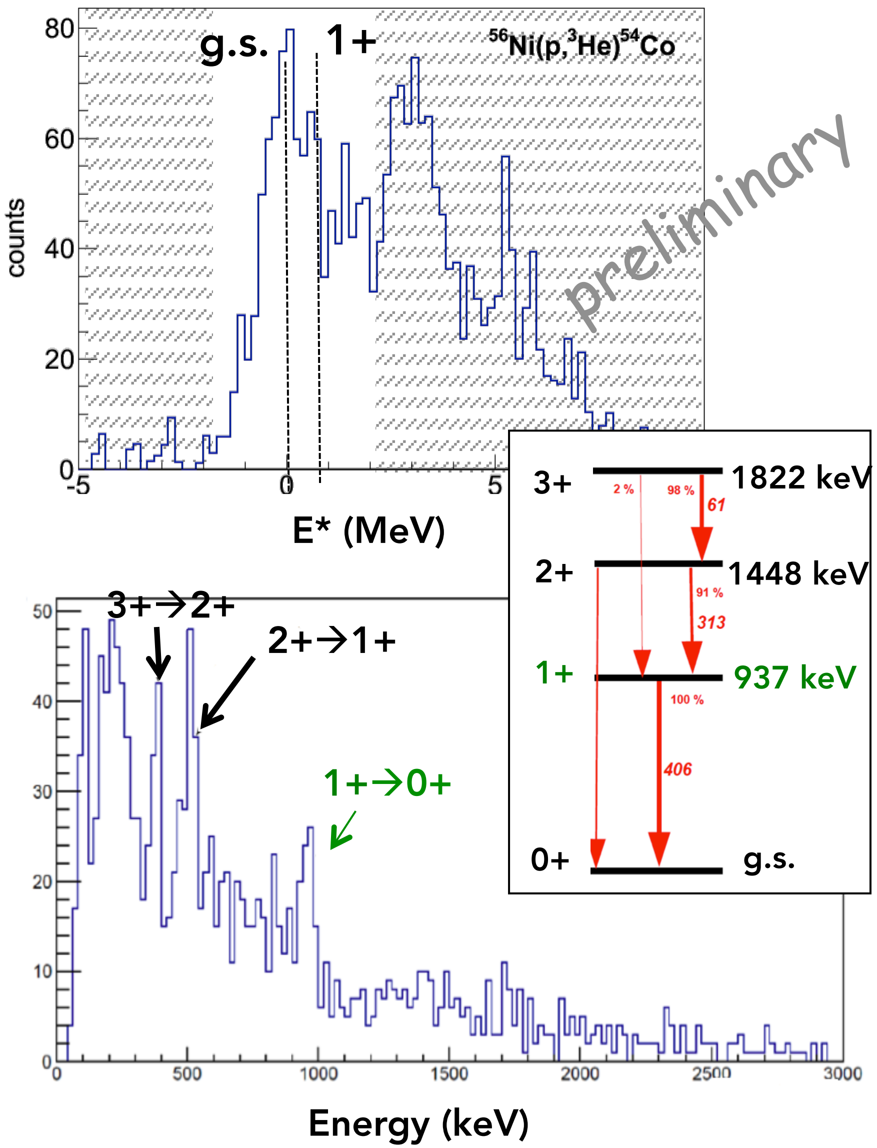




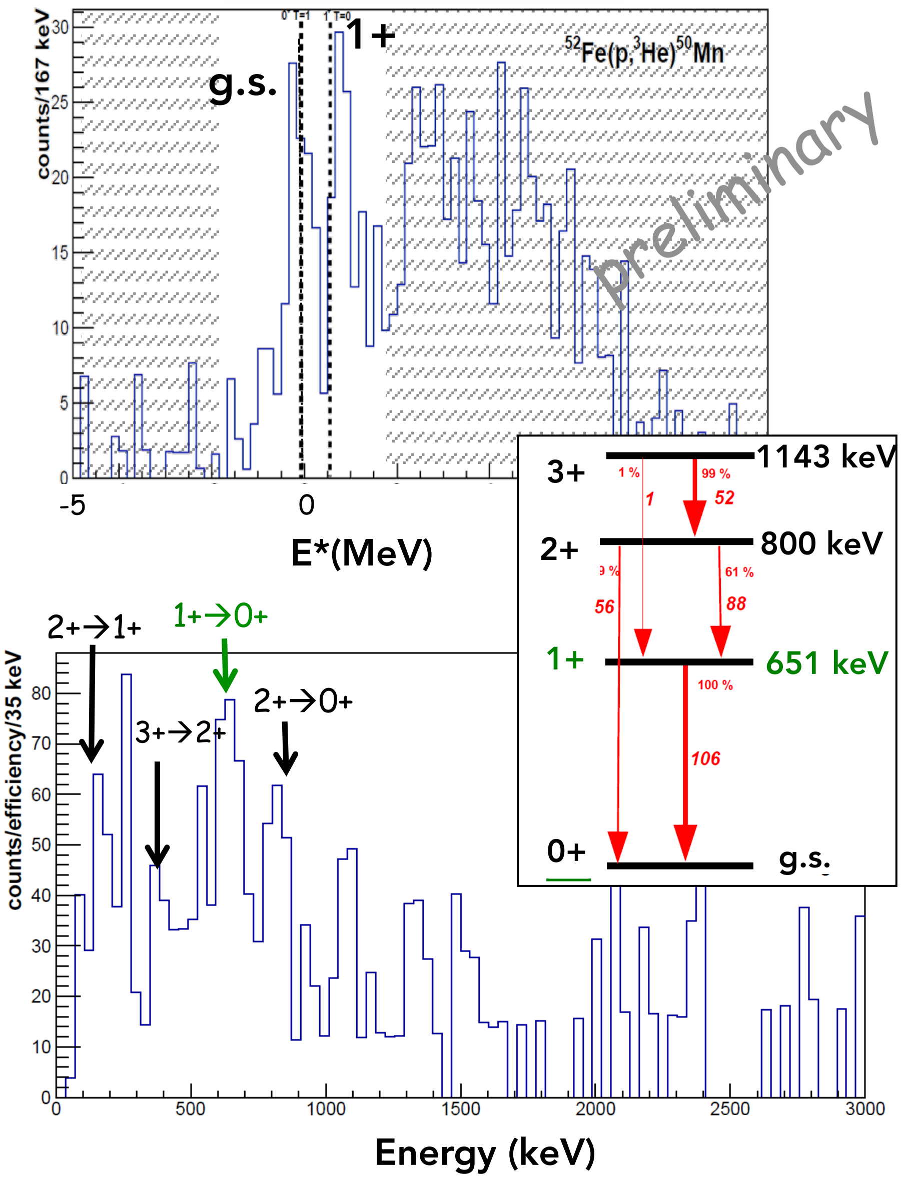


Excitation energy spectra

$^{56}Ni(p,^{3}He)^{54}Co$



$^{52}Fe(p,^{3}He)^{50}Mn$



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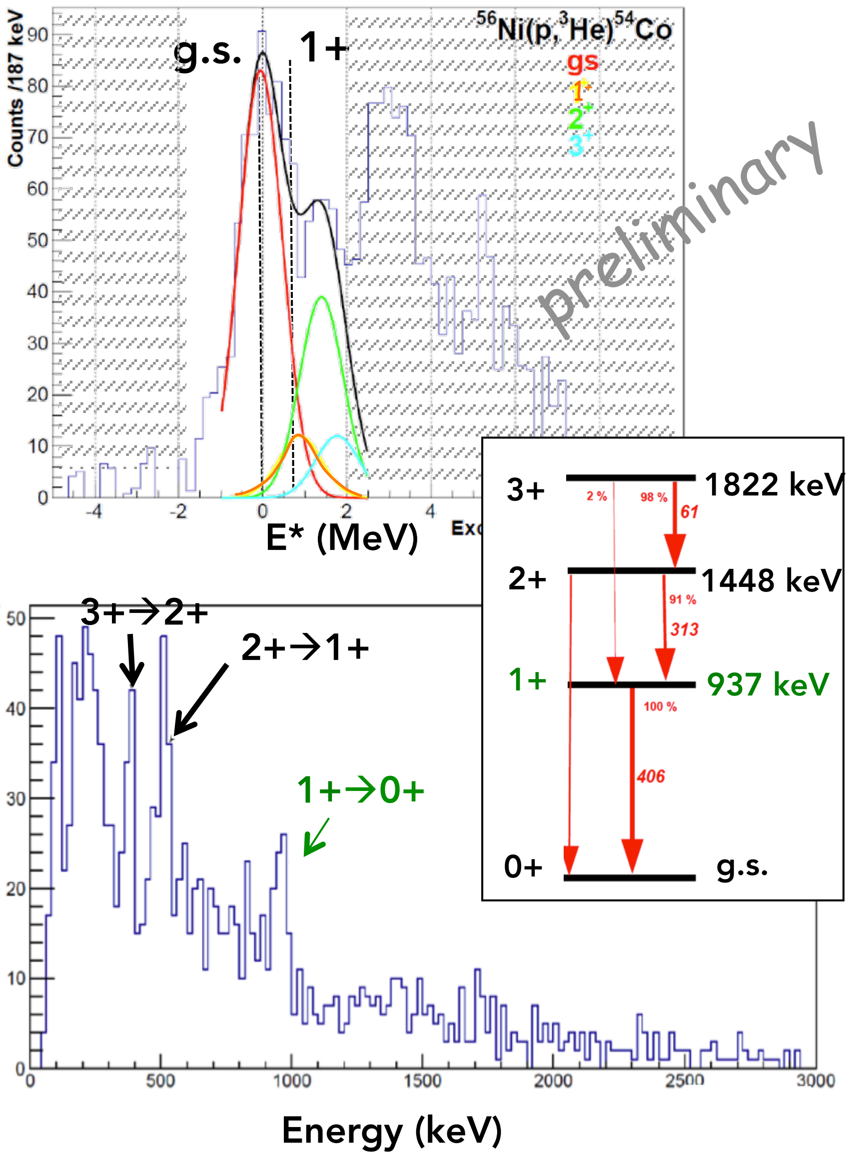

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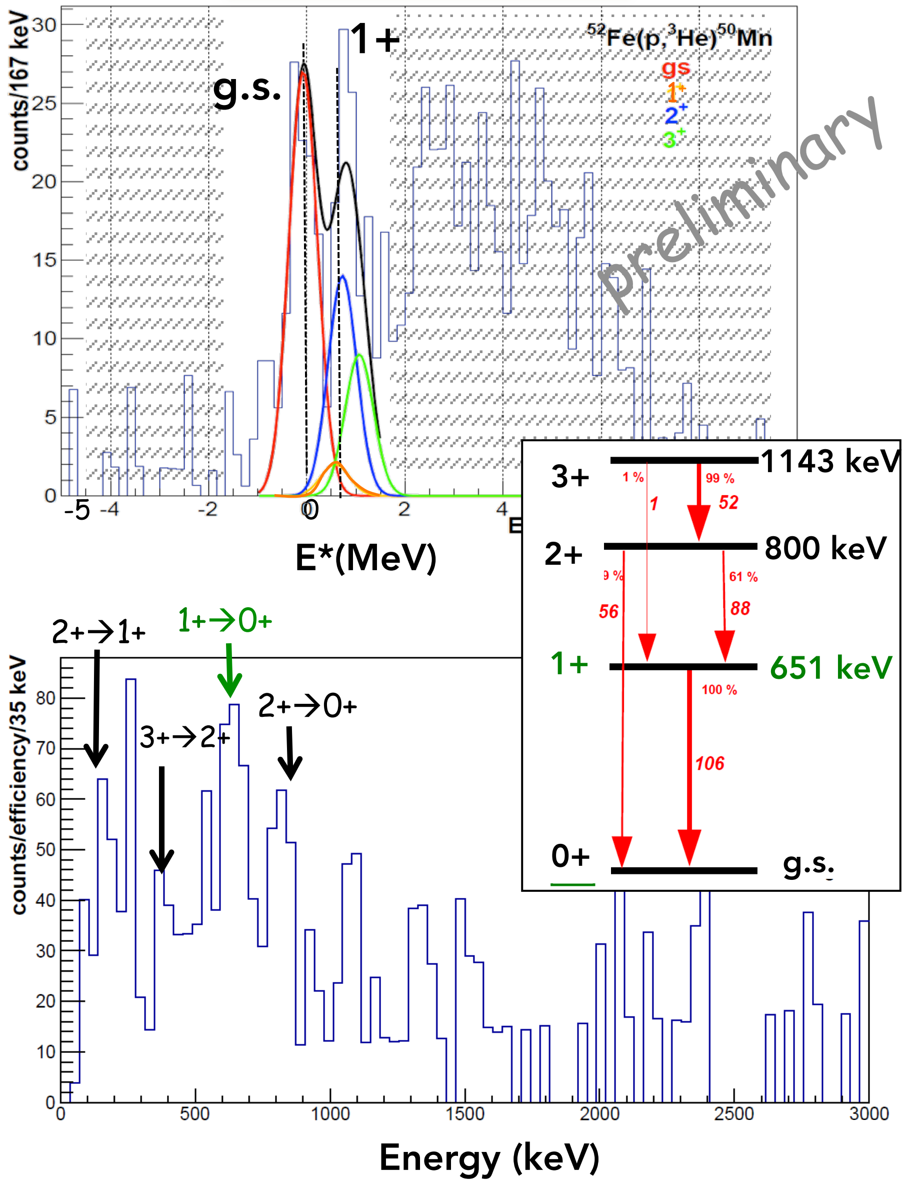
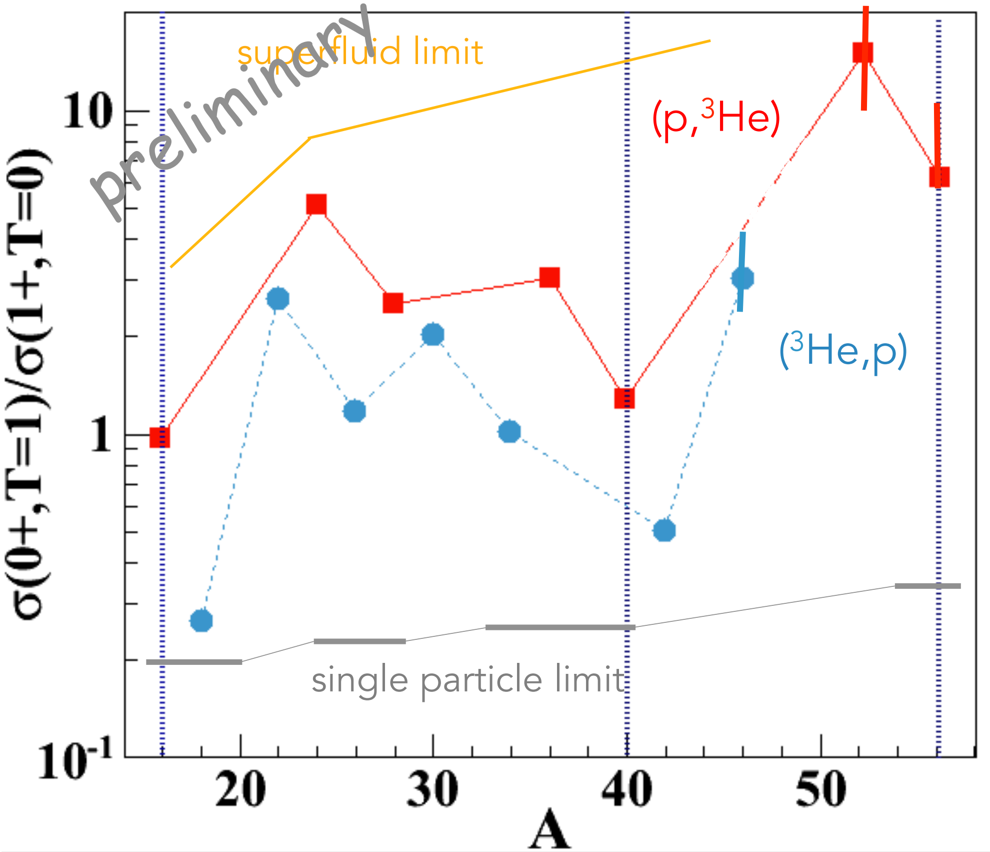


Results for ^{52}Fe and ^{56}Ni



- Particle-gamma coincidences very powerful
- T=0 states sparsely populated
- Parabola behaviour
- ^{56}Ni is less single-particle than expected
- T=0 pairing seems weaker in fp shell than sd shell

Perspectives :

- ^{56}Ni(d,α)^{54}Co : complementary reaction with selectivity in isospin
- angular distribution

Thank you for your attention

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