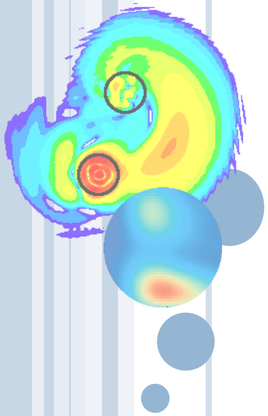
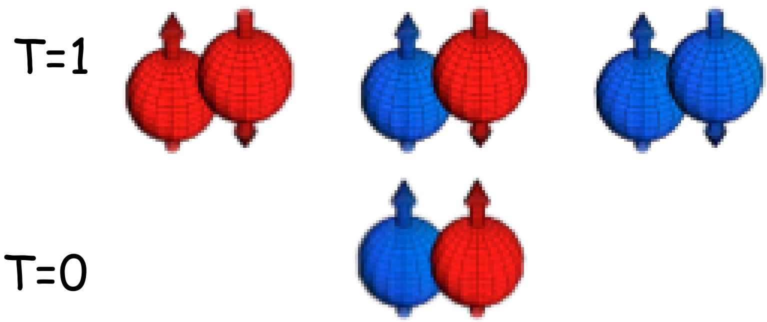
STUDY OF NEUTRON-PROTON PAIRING IN N=Z UNSTABLE NUCLEI THROUGH TRANSFER REACTIONS

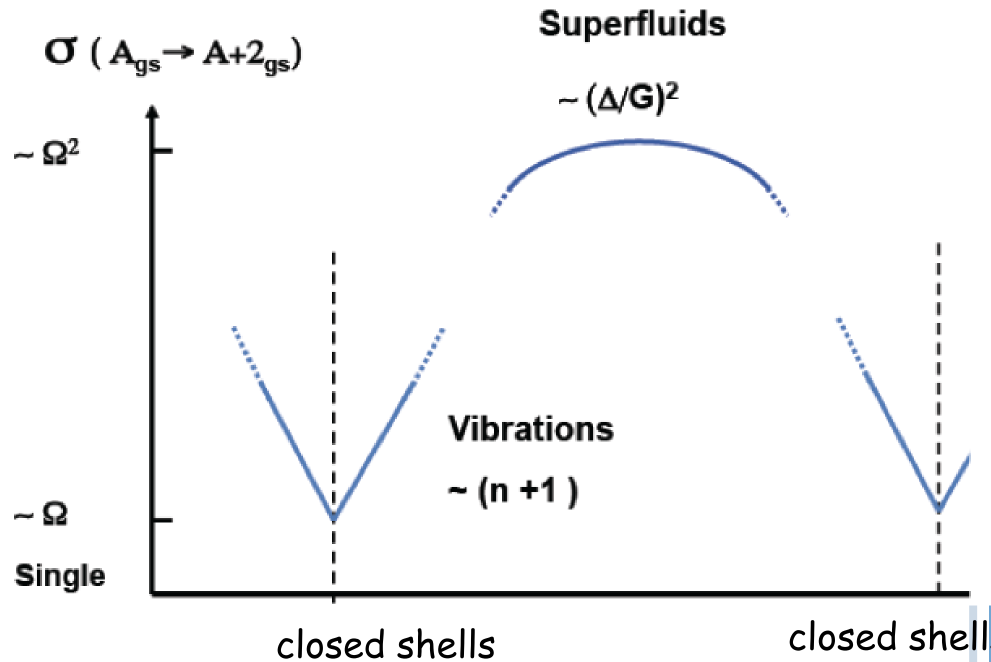


- -> Pairing in nuclei
- -> fp shell nuclei & effect of spin orbit
- -> Experimental set-up
- -> ^{56}Ni(p,d) : one-nucleon transfer
- -> ^{56}Ni (p,3He) : preliminary results

M. Assié, B. Le Crom, Y. Blumenfeld (IPN Orsay)

T=0/T=1 pairing





- N=Z nuclei, unique systems to study *np* correlations

  As you move out of N=Z *nn* and *pp* pairs are favored

- Role of isoscalar (T=0) and isovector (T=1) pairing

  Large spatial overlap of *n* and *p*

  Pairing vibrations (normal system)

  Pairing rotations (superfluid system)

  Does isoscalar pairing give rise to collective modes?

Possible probes

BE differences can be described by an appropriate combination of the symmetry energy and the isovector pairing energy. Evidence for full isovector pairing (nn,np,pp) - charge independence. *A.O Macchiavelli (PRC 2000)*

Rotational properties ("delayed alignments") consistent with T=1 cranking model. *Fischer, Lister - Afanasjev, Frauendorf*

Spin-aligned neutron-proton coupling scheme in ^{92}Pd
B. Cederwall et al. , Nature 2011 & Piet Van Isacker PRL (2005)

Deuteron transfer reaction : $< A+2|a^+a^+|A >$

Fröbrich *(Phys. Lett. 1971) -> 2.5 enhancement factor*

analogous to the transition probabilities BE2's on the quadrupole case.

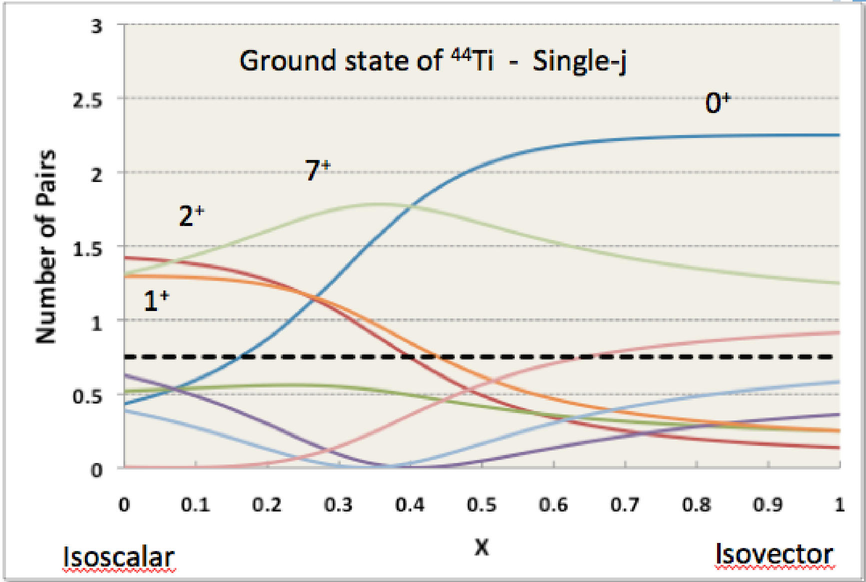
T=0 pairing by transfer reaction

✧ Deuteron-transfer intensities from IBM model

Limit	Reaction	$C^2_{T=0}$	$C^2_{T=1}$
$b/a = 0$	$\mathrm{EE} \to \mathrm{OO}_{T=0}$	$\frac{1}{2}(N_b + 6)$	0
SU(4) limit	$\mathrm{EE} \to \mathrm{OO}_{T=1}$	0	$\frac{1}{2}(N_b + 6)$
	$\mathrm{OO}_{T=0} \to \mathrm{EE}$	$\frac{1}{2}(N_b + 1)$	0
	$\mathrm{OO}_{T=1} \to \mathrm{EE}$	0	$\frac{1}{2}(N_b + 1)$
$b/a \ll -1$	$\mathrm{EE} \to \mathrm{OO}_{T=0}$	$N_b + 3$	0
isoscalar	$\mathrm{EE} \to \mathrm{OO}_{T=1}$	0	3
	$\mathrm{OO}_{T=0} \to \mathrm{EE}$	$N_b + 1$	0
$b/a \gg +1$	$\mathrm{EE} \to \mathrm{OO}_{T=0}$	3	0
isovector	$\mathrm{EE} \to \mathrm{OO}_{T=1}$	0	$N_b + 3$
	$\mathrm{OO}_{T=1} \to \mathrm{EE}$	0	$N_b + 1$

van Isäcker, PRL (2005)

✧ Case of ^{44}Ti g.s.

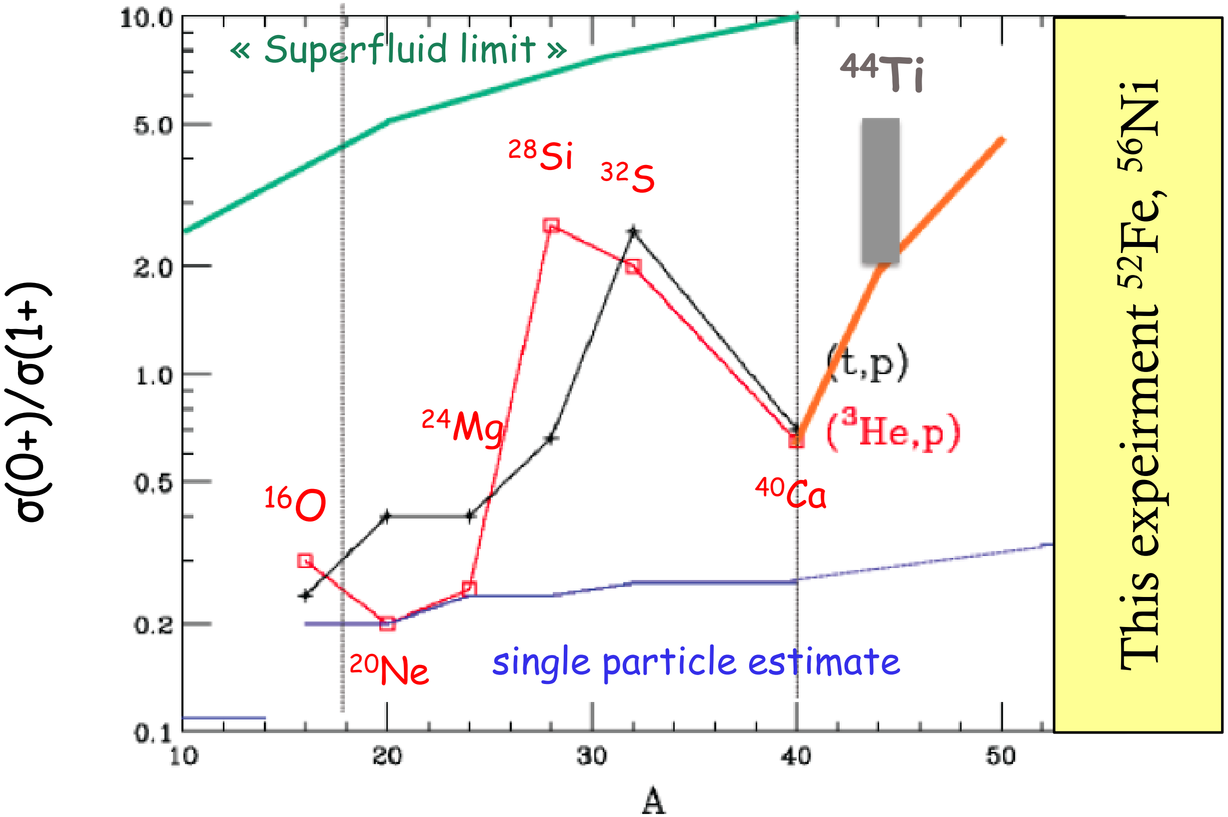


from A.O. Macchiavelli, Eurisol Topical meeting

→ transfer is proportionnal to the number of pairs

→ σ (0⁺)/σ (1⁺)= gives the relative strength of T=0/T=1 pairing

Transfer measurements : where do we stand ? comparison with (t,p)



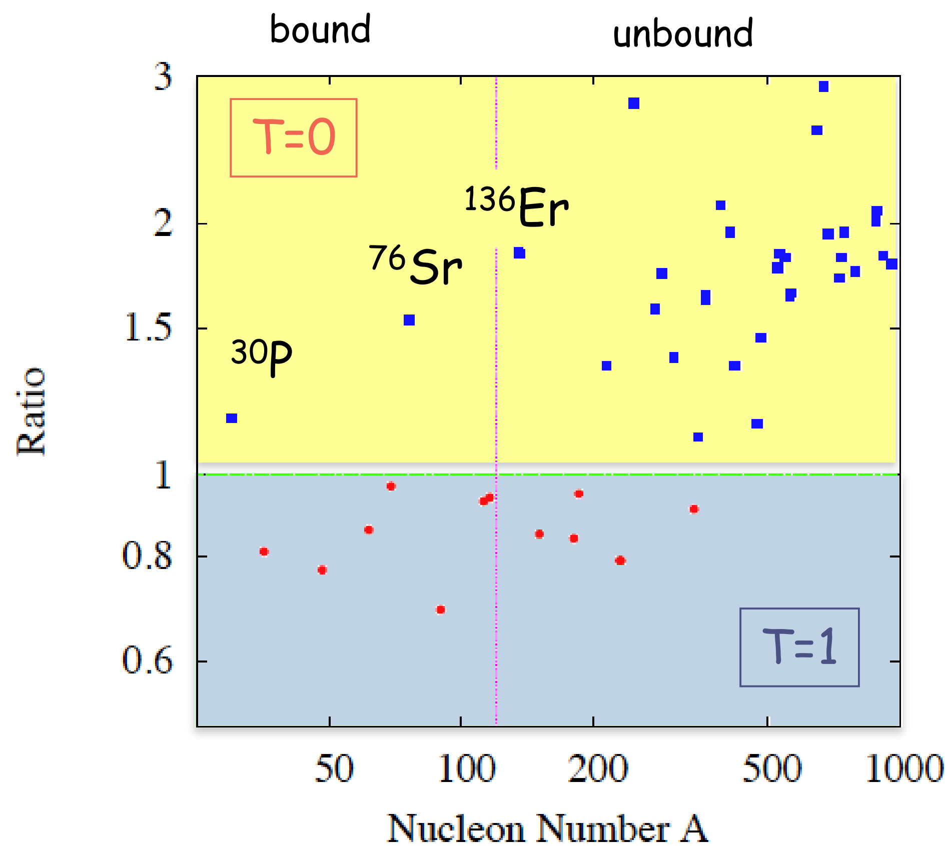
from A.O. Macchiavelli

- New measurements of (^{3}He,p) and (p,^{3}He) in sd shell @ RCNP Osaka
- Measurement of ^{44}Ti from **A.O. Macchiavelli**

In nuclei : T=0/T=1 pairing

		T=1	T=0	overlap
		$\langle QM \vert iv\rangle$	$\langle QM \vert is\rangle$	$\langle iv \vert is\rangle$
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

Sambatoro, Sandulescu, Johnson, PRC (2015)



Bertsch, Luo arXiv:0912.2533v1

Gezerlis et al, PRL (2011)

New experiment@GANIL to extend the systematics ^{56}Ni and ^{52}Fe (p, ^{3}He)

T=0 pairing by transfer reaction

✧ Transfer reaction

reaction	beam E	direction	selectivity
(p,^{3}He)	>20 MeV	forward	ΔT=0,1
(^{3}He,p)	low <5MeV	backward	ΔT=0,1
(d,α)	>20 MeV	forward	ΔT=0
(α,d)	low <5MeV	backward	ΔT=0

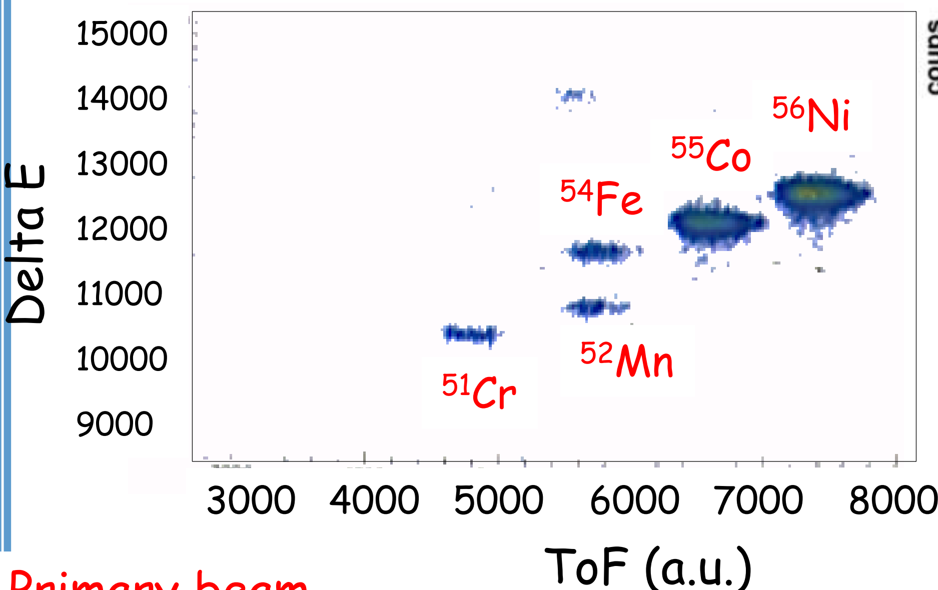
✧ Best nucleus to study :

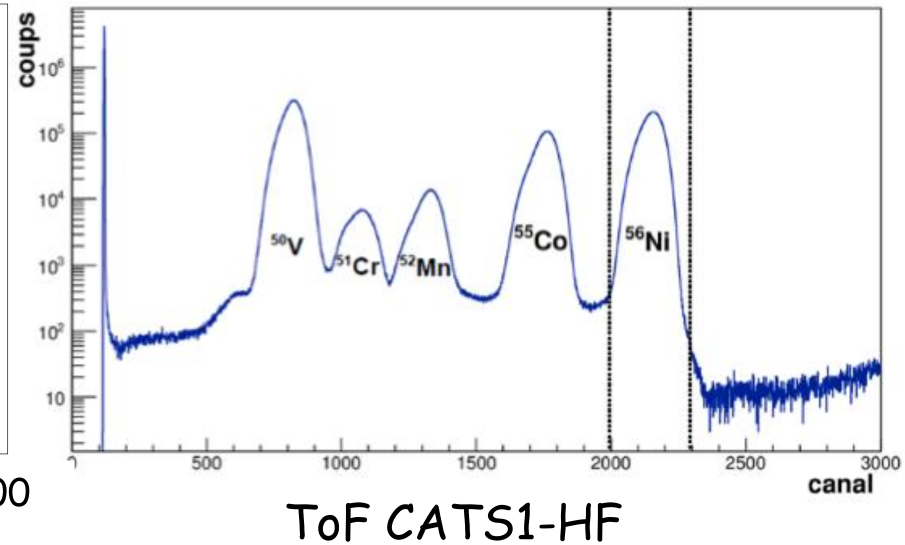
. N=Z nuclei with high j orbitals to develop collectivity

$g_{9/2}$ shell like ^{92}Pd *not accessible experimentally*

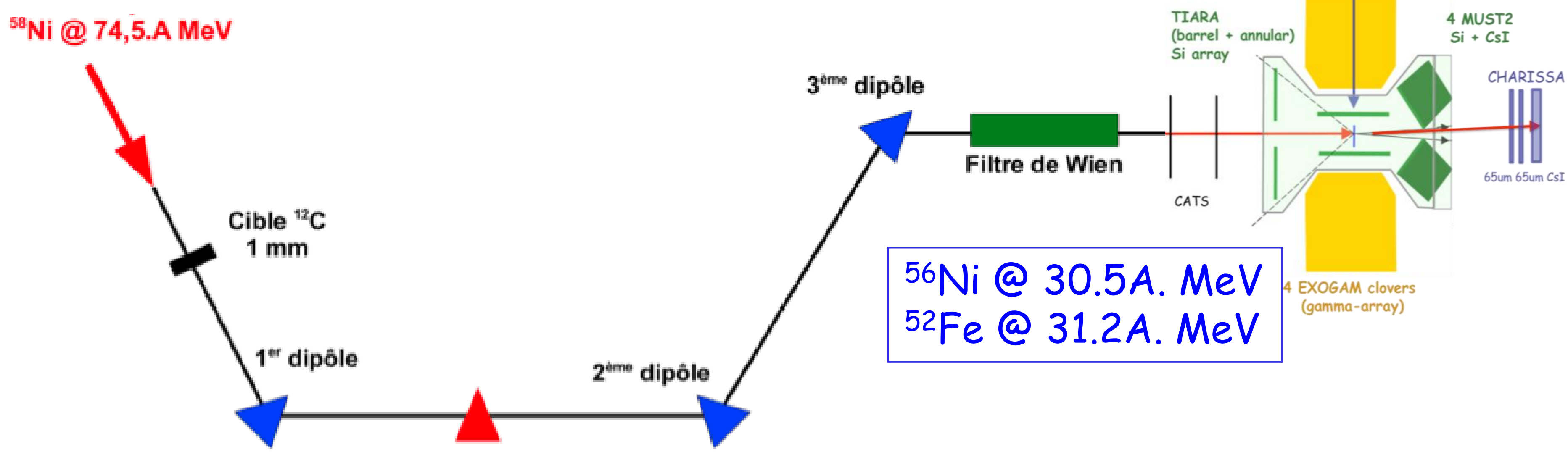
. only sd and fp shell nuclei available

Beam production





Primary beam
^{58}Ni & 74.5A MeV



^{56}Ni @ 30.5A. MeV
^{52}Fe @ 31.2A. MeV

Motivations & meaurement

- Beam produced by fragmentation with the LISE spectrometer

  ^{56}Ni, ^{52}Fe @ 30A MeV

- Reactions measured :

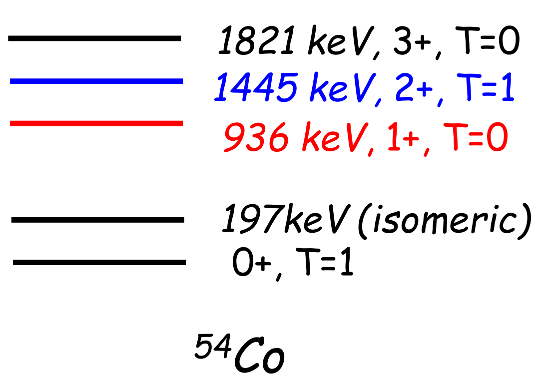
  ^{56}Ni (p,^{3}He) ^{54}Co

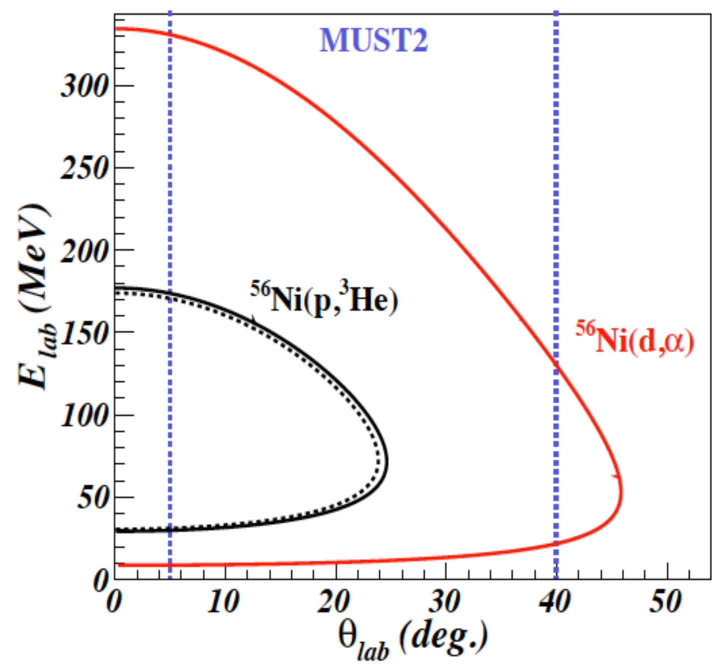
  ^{56}Ni (d,^{4}He) ^{54}Co

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

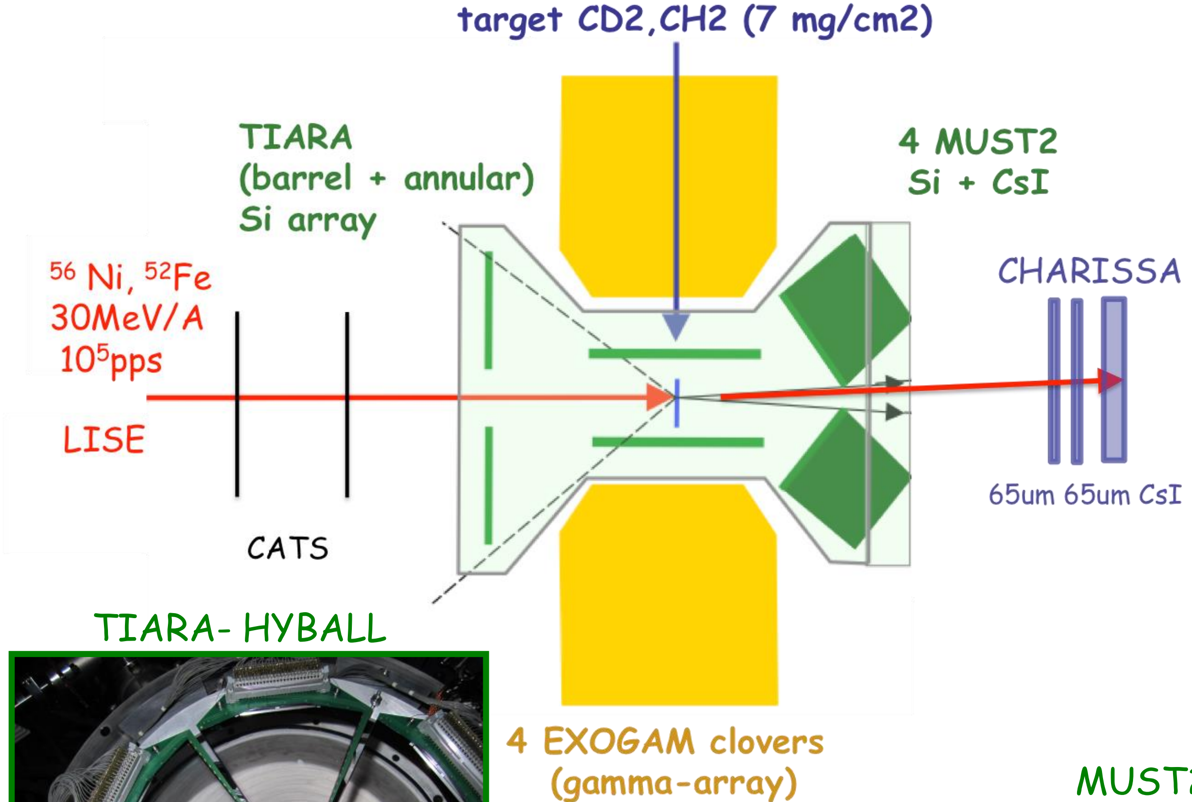
- thick targets : 7 mg/cm^2

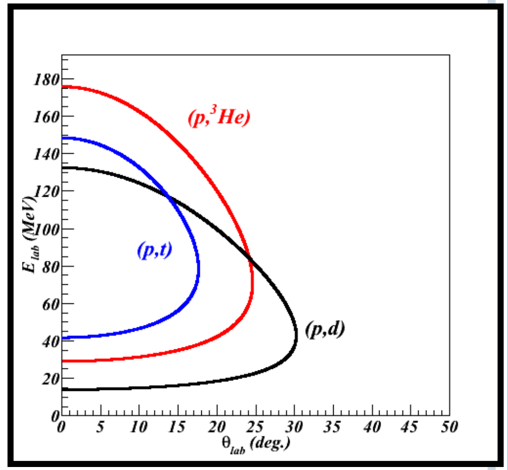
- Odd-Odd nucleus level Scheme



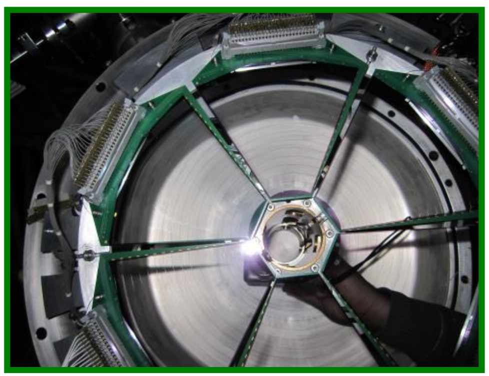


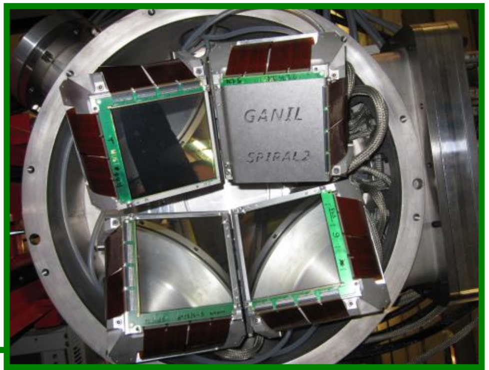
Pairing in the T=0 or 1 np channel : GANIL experiment



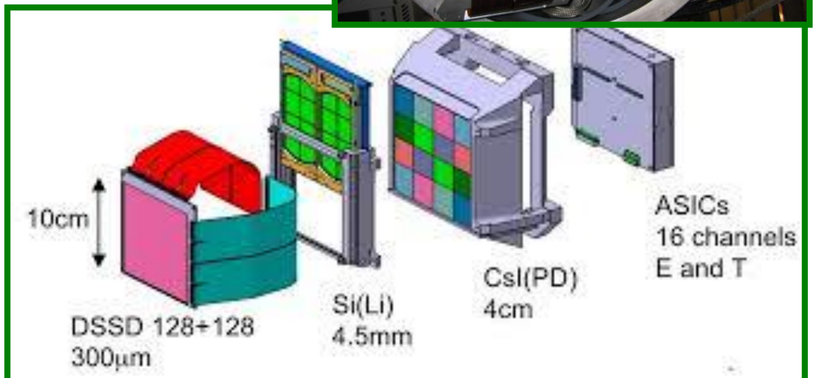


TIARA- HYBALL





MUST2



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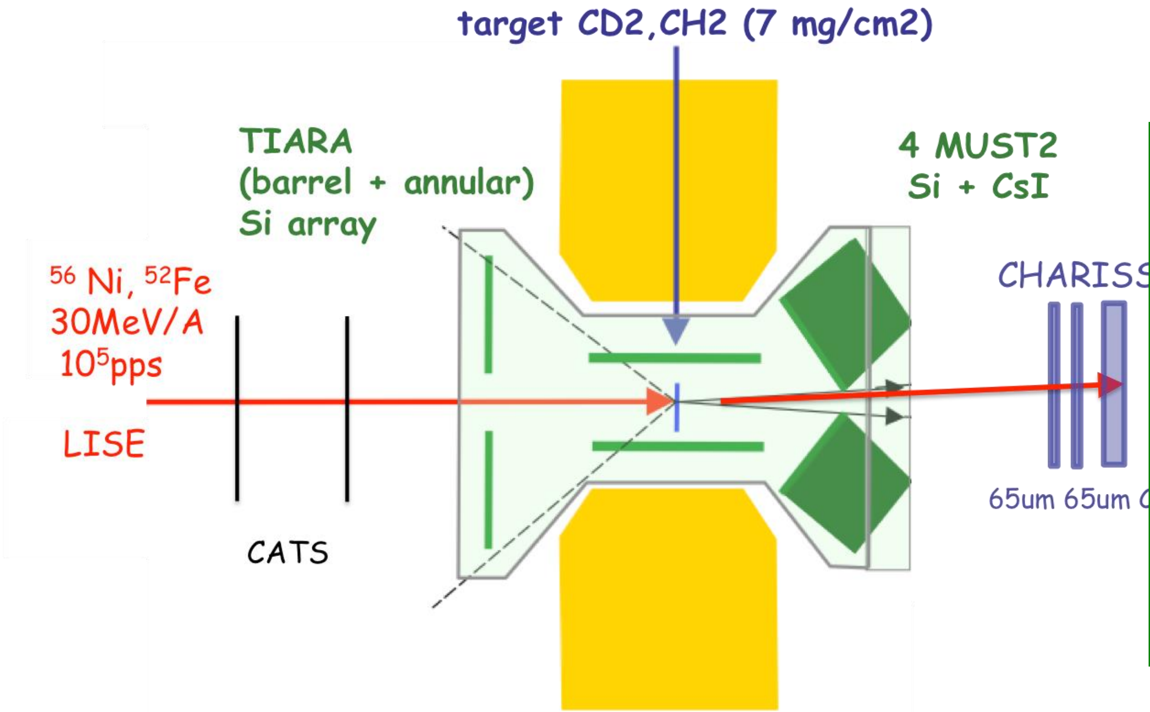
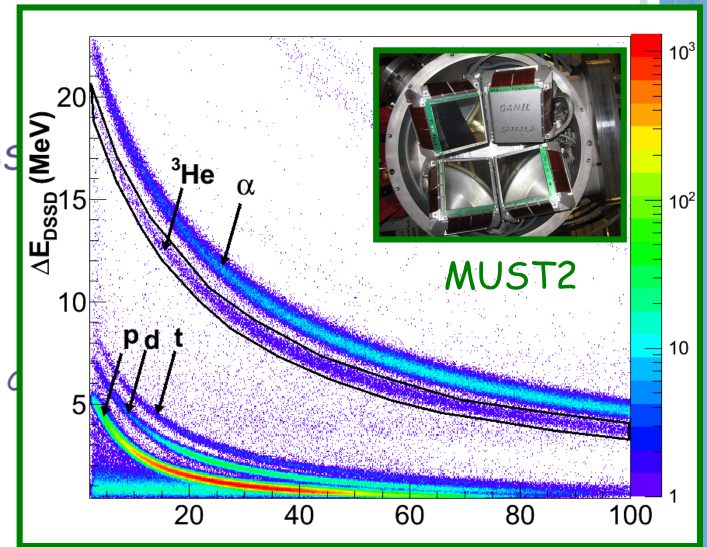


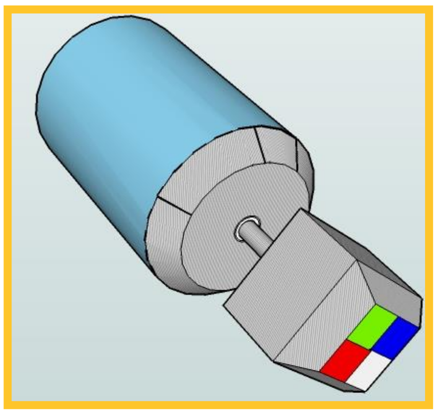


MUST2

——	2+, T=1
——	1+, T=0 *(d transfer)*
	isomeric state
——	
——	0+, T=1

Generic Level scheme

4 EXOGAM clovers



Efficiency ~8%@ 1 MeV

Energy resolution 3 keV

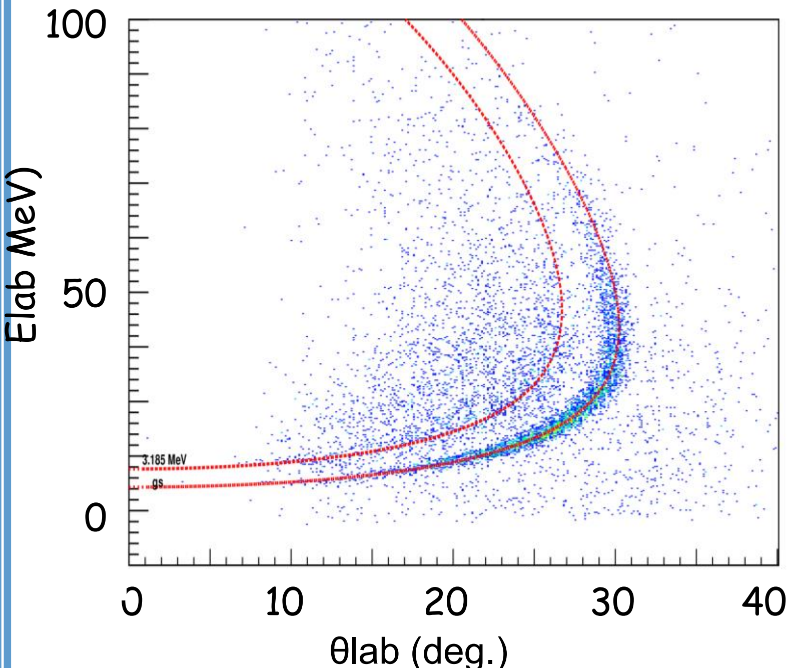
Doppler broadening 80 keV

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

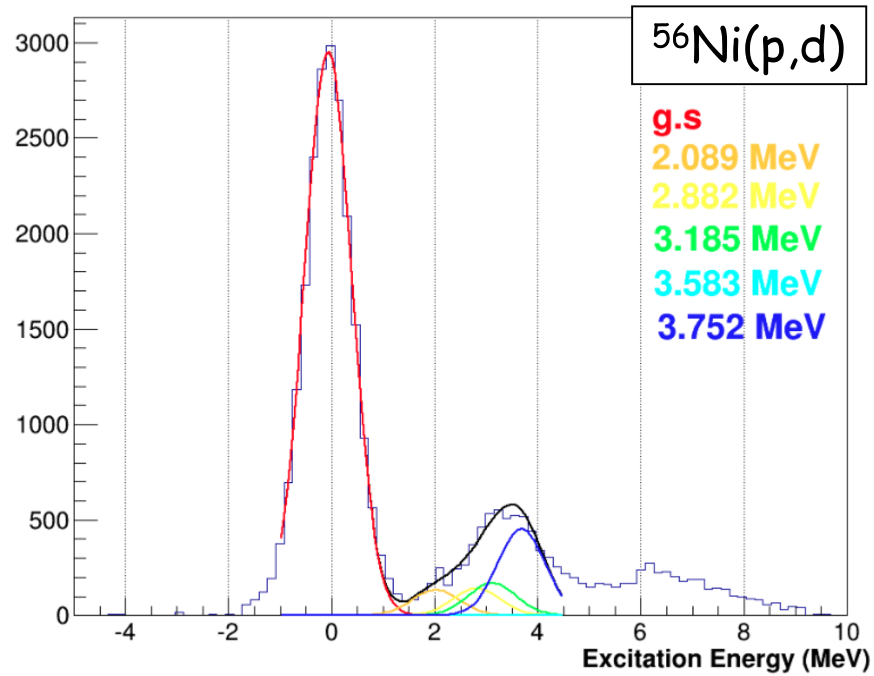
^{56}Ni(p,d) already measured @ MSU *(Sanetullaev et al, PLB 2014)*

- energy calibration of MUST2
- alignement CATS-MUST2
- resolution = 846 keV (FWHM) as expected from simulations

Kinematical line



846 keV FWHM
(in agreement with simulations)



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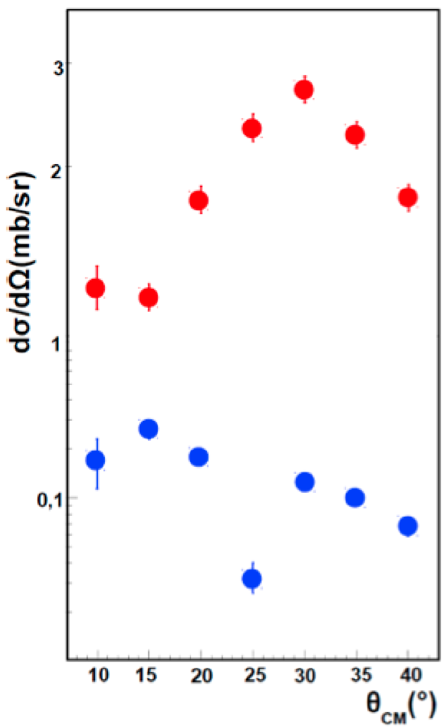
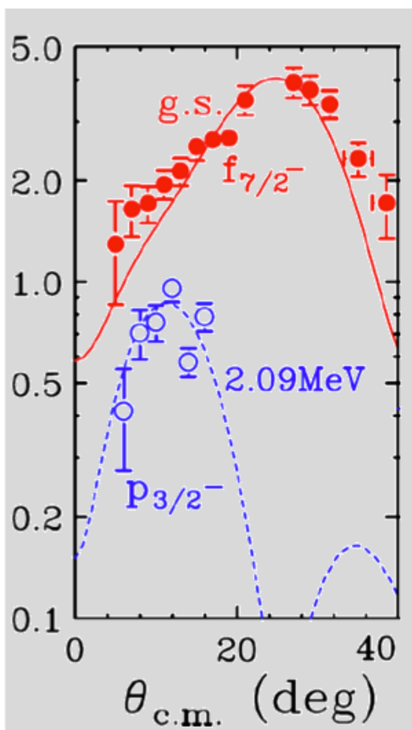
g.s. angular distribution
and DWBA $f_{7/2}$ SF=6.8 (id. PLB2014)





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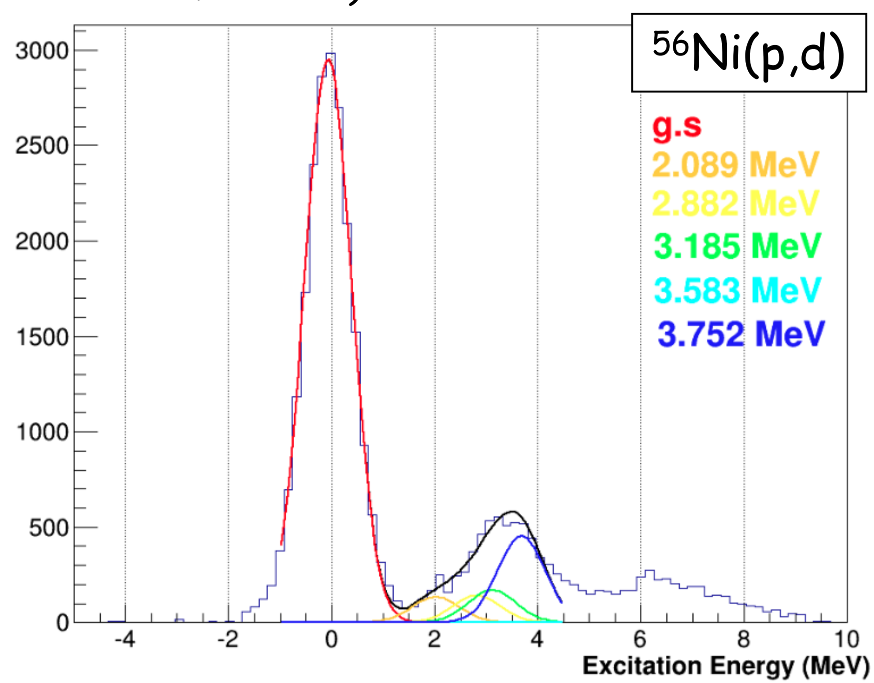

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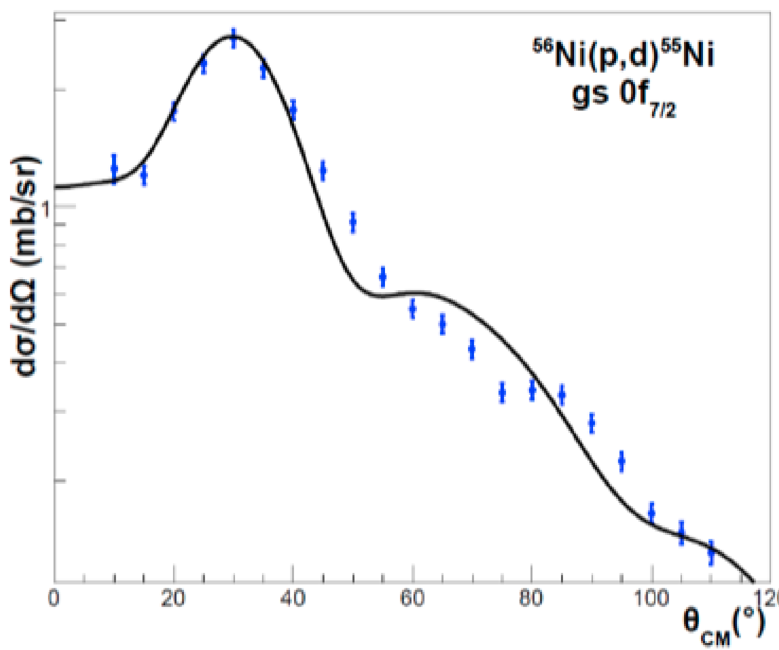
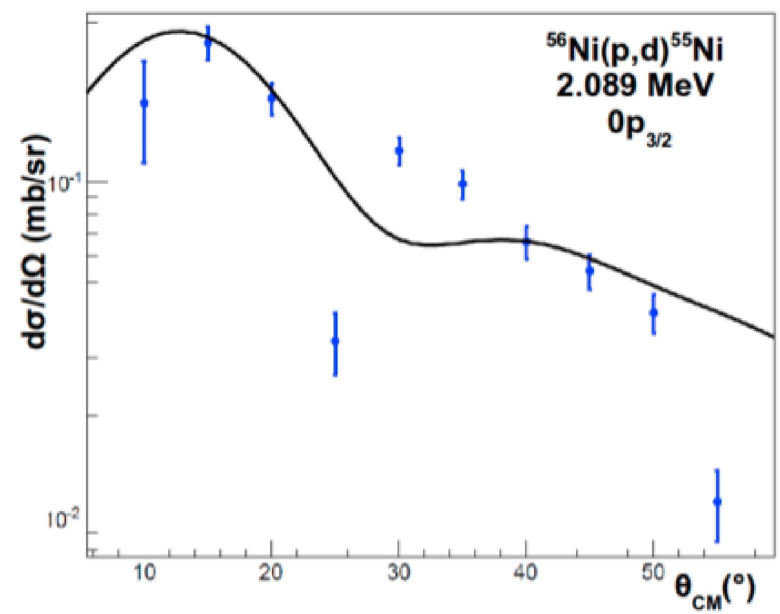


1+ (exicted state) angular distribution
and DWBA $f_{7/2}$

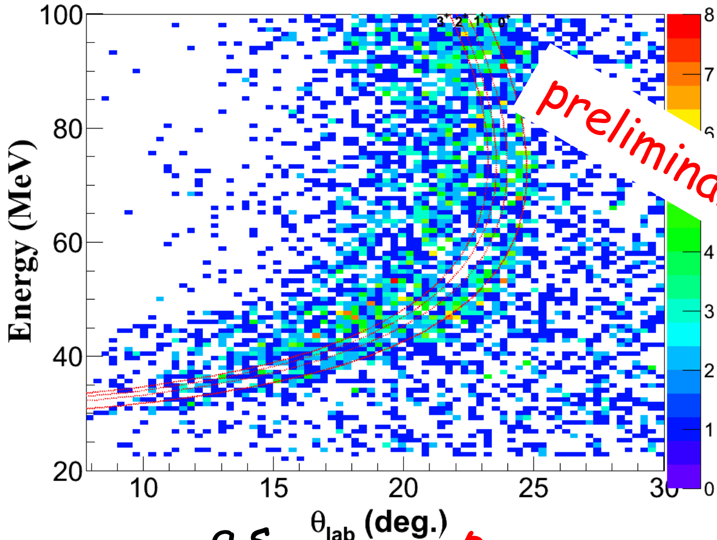


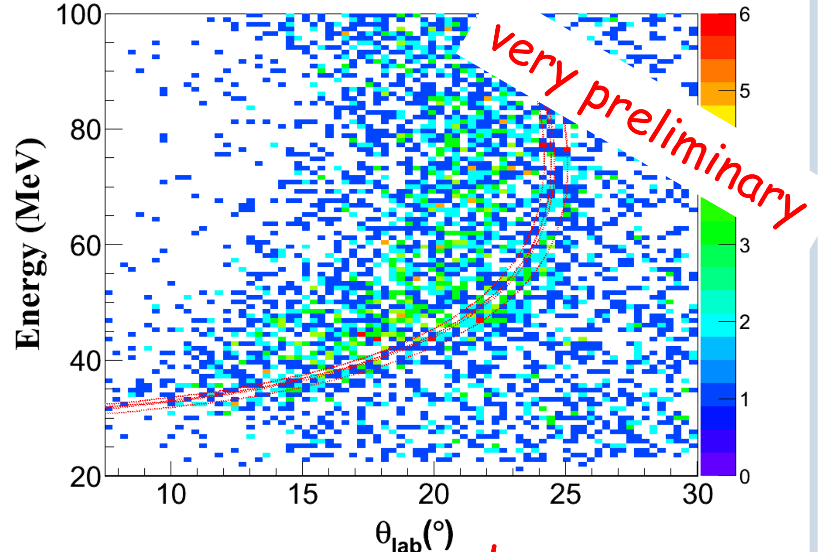
Pairing in the T=0 or 1 np channel

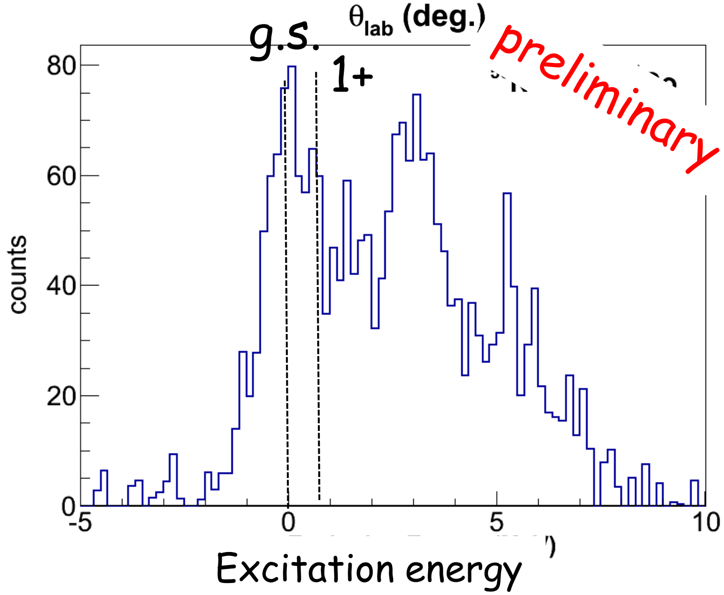
^{56}Ni (p,^3He) ^{54}Co

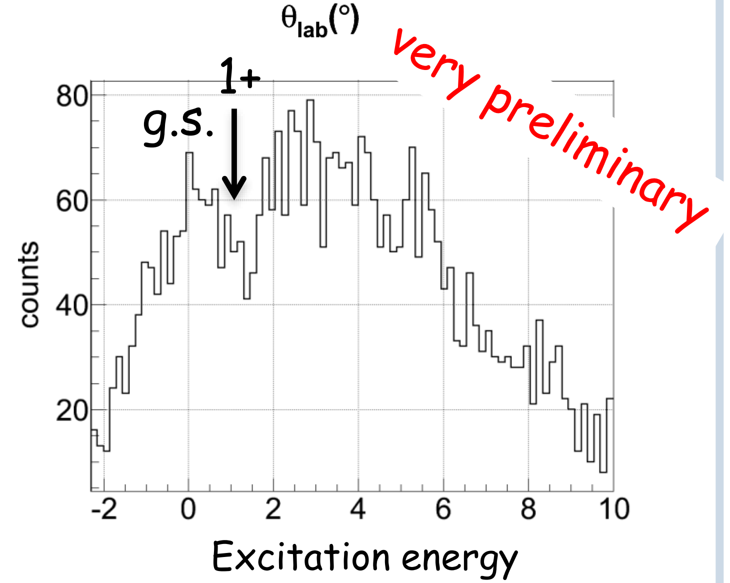
E* resolution = 450 keV

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

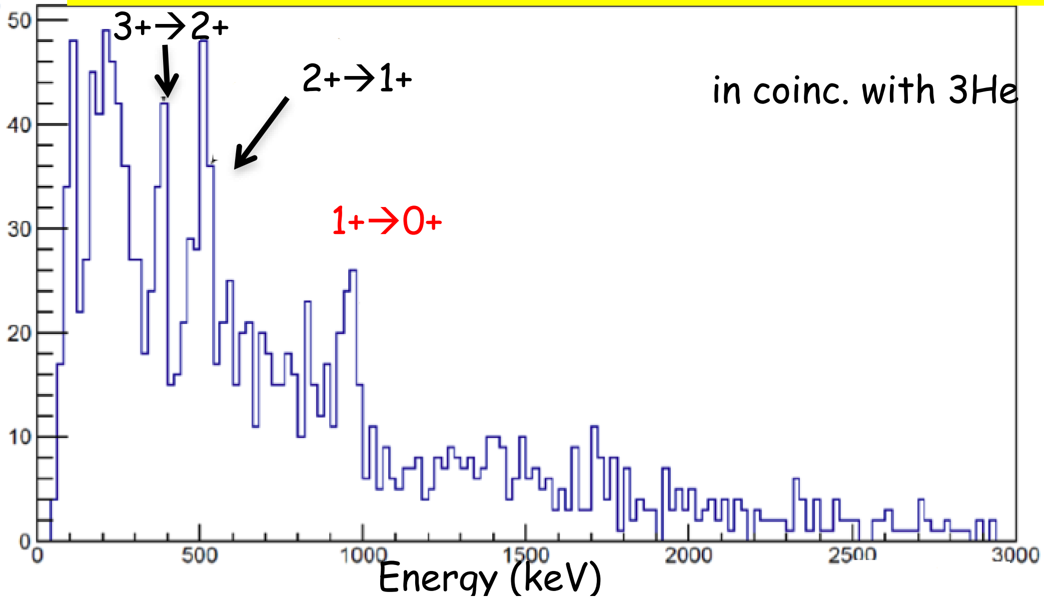


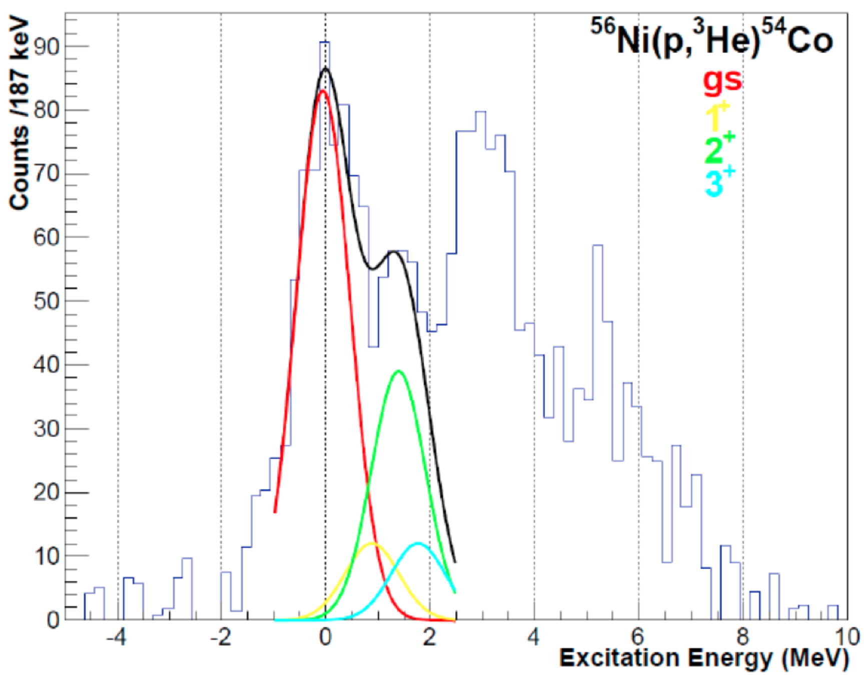


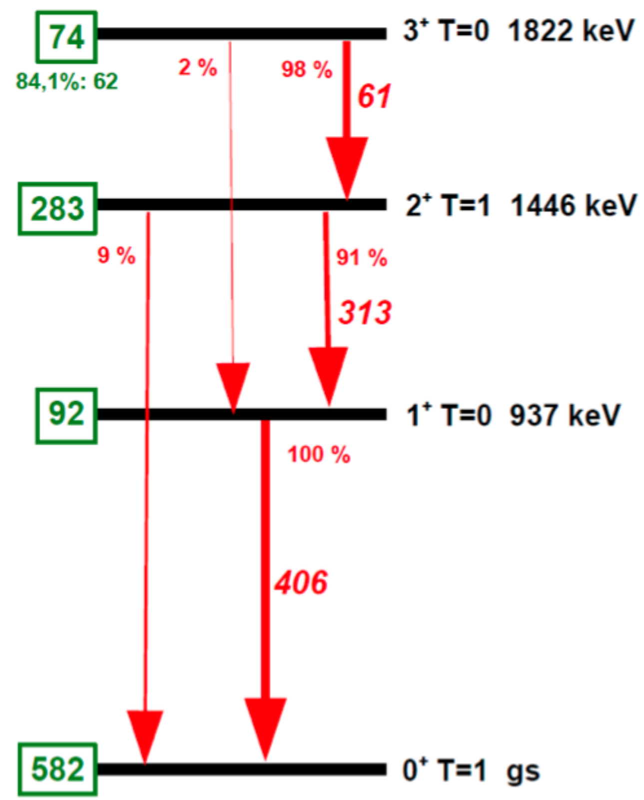




Pairing in the T=0 or 1 np channel : case of ^{56}Ni







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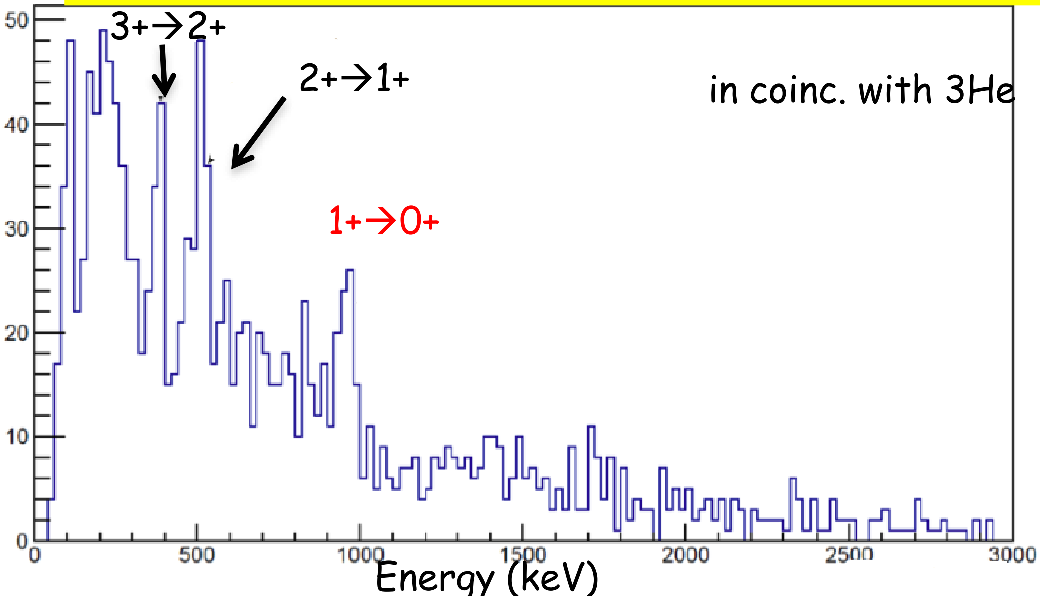
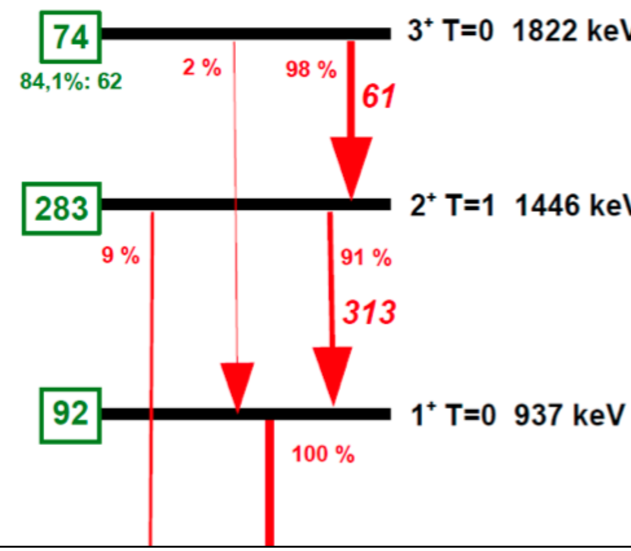
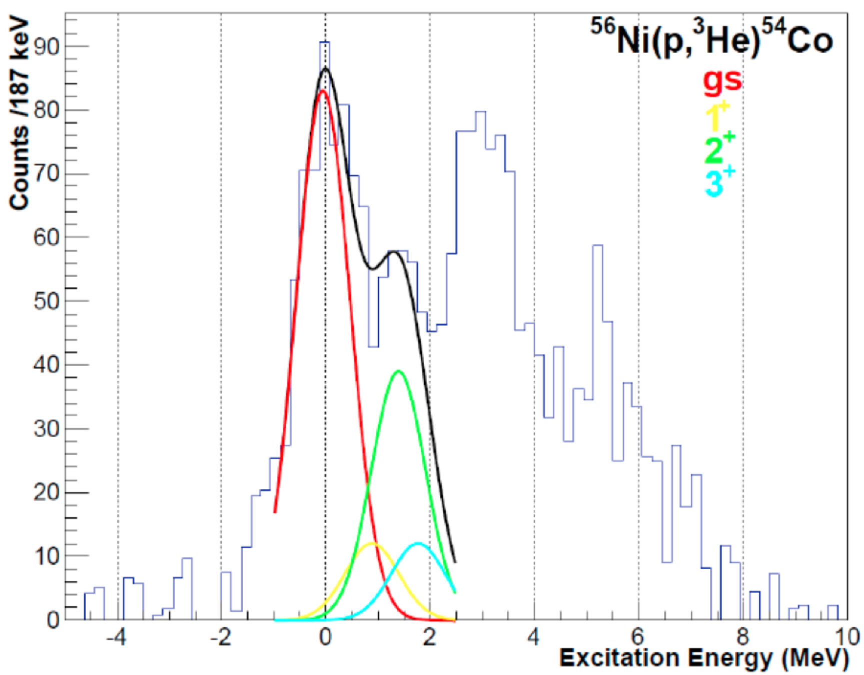
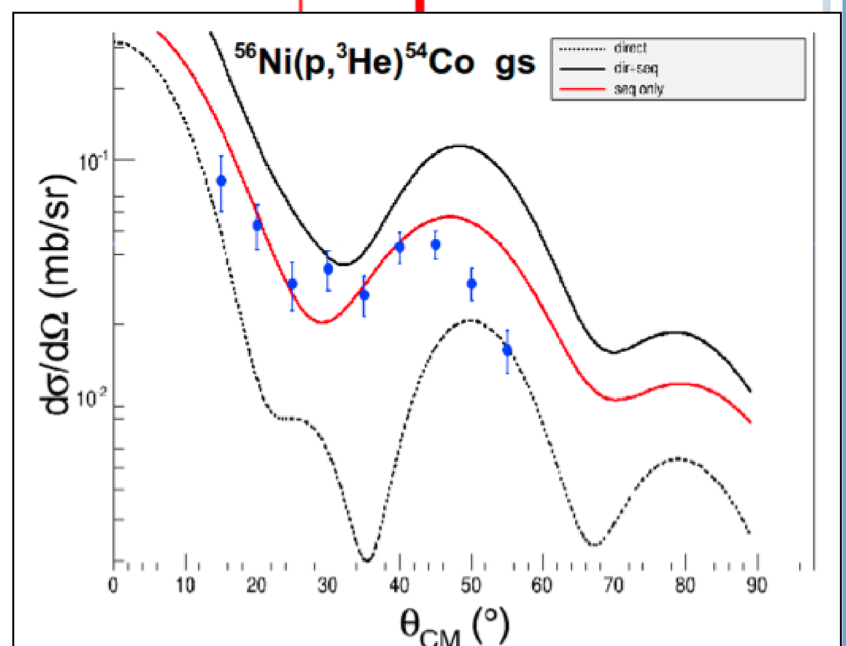




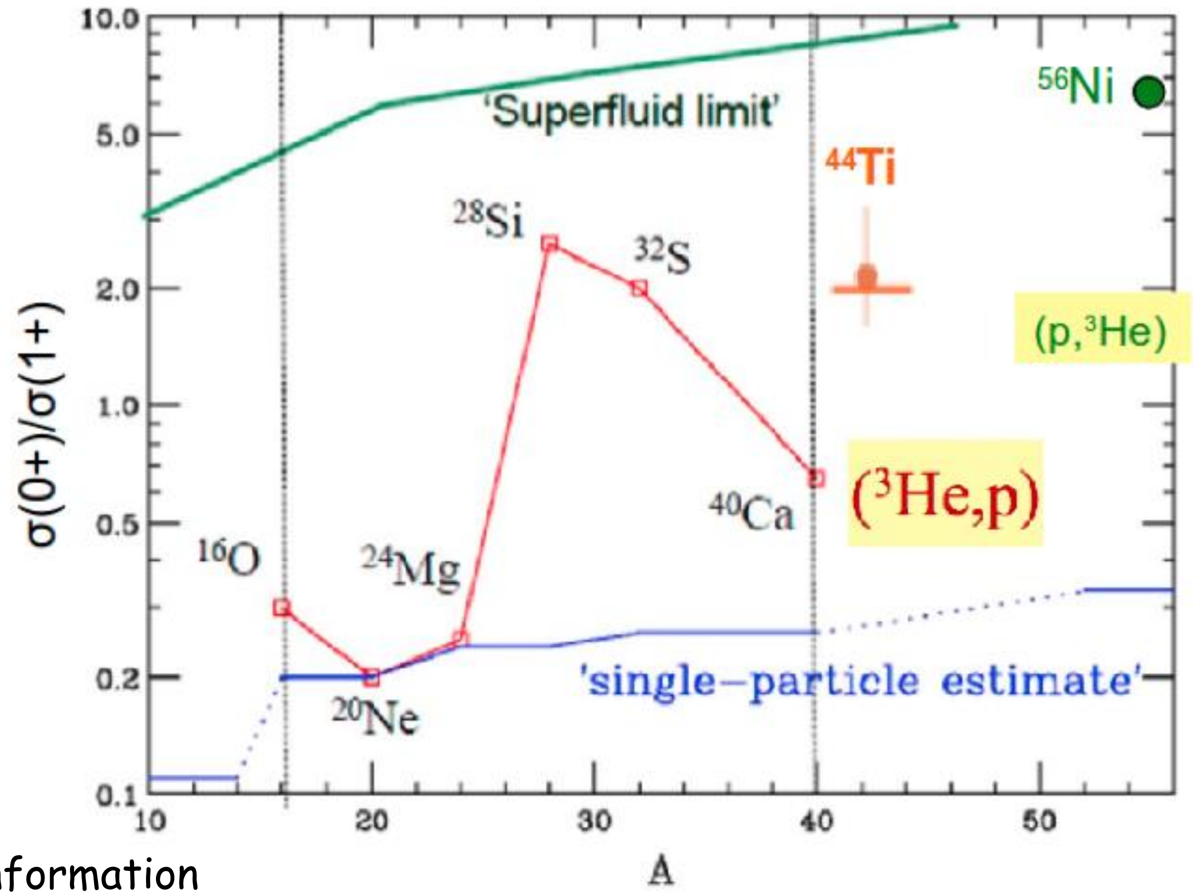




Pairing in the T=0 or 1 np channel : case of ^{56}Ni

From theoretical side :

- form factors including other shells than f7/2 (H. Sagawa)
- beyond MF (+SM) calculations (D. Gambacurta)
- 2nd order DWBA



From experimental side :

- analysis of ^{56}Ni(d,alpha) in progress (complementary information on isomeric state population)
- analysis of data ^{52}Fe(d,alpha)

THANK YOU

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