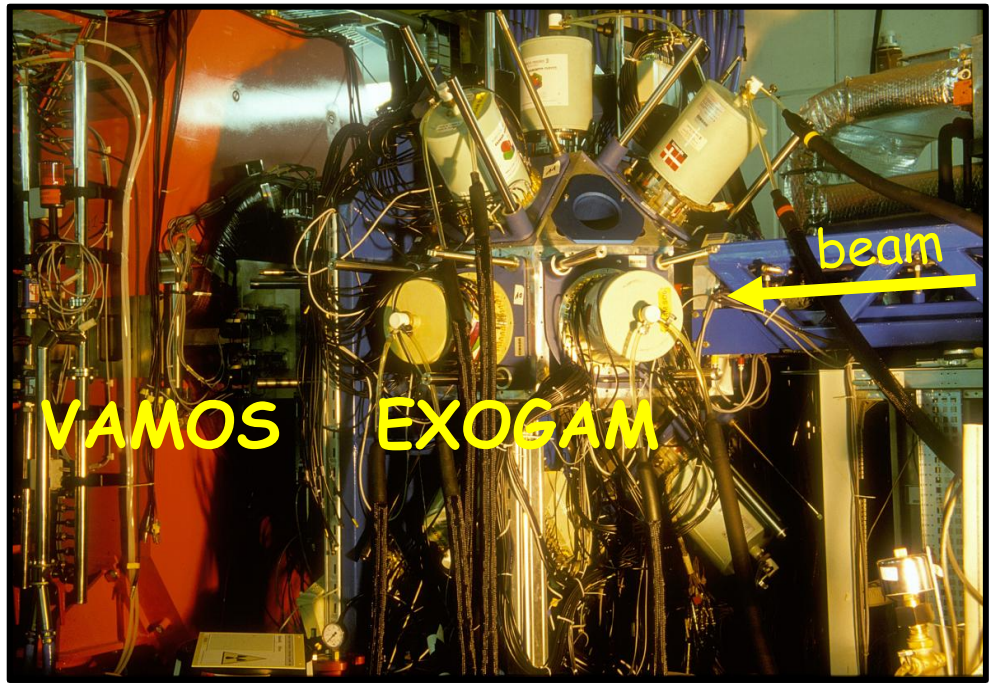
γ-ray spectroscopy of neutron-rich nuclei around N=20



Marie Gélin
GANIL

γ-ray spectroscopy of neutron-rich nuclei around N=20

- Motivations :

→ collect new spectroscopic information in "island of inversion" region

1. $^{32}_{12}Mg_{20}$
2. $^{34}_{14}Si_{20}$
3. Other nuclei in this region

- How ?

1. New method : direct reactions with cocktail beam
2. Complete identification before and after the target
3. Coincidence γ detection (EXOGAM) → angular distributions, γγ coincidences

→ Determination of level schemes and multipolarity assignment

2.32 MeV state in ^{32}Mg: 4$^+$ or 3$^-$?

$E(2^+)$ = 885 keV

✓Time delayed βγγ(t) measurement : [H.Mach et al., EPJA 25, 105 (2005)]

$T_{1/2}(2^+)$ = 16(4.2) ps B(E2; $2^+ \rightarrow 0^+$) = 327(87) e^2fm^4: Highly Deformed.

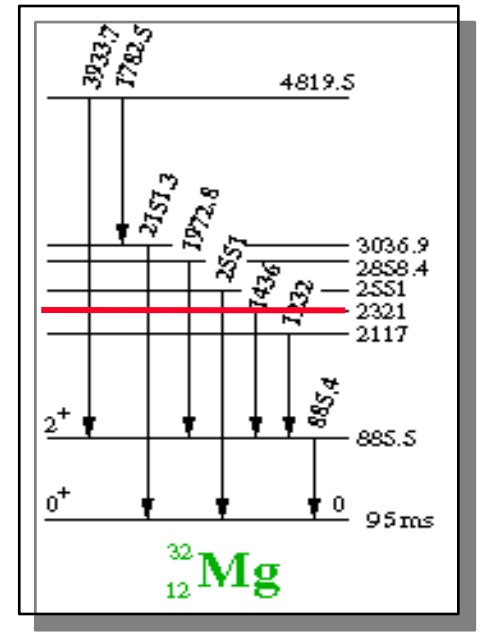
✓In beam γ-ray spectroscopy (fragmentation) : [F.Azaiez et al., EPJA 15,93 (2002)].

2.321 MeV state is a 4^+: $E(4^+)/E(2^+)$ = 2.6

✓ β-decay of ^{32}Na : [G. Klotz et al. PRC 47, 2502 (1993)]

2.32 MeV state is strongly populated (logft = 5.4)

if GS of ^{32}Na is a 3^- or 4^- (SM) then 2.32 MeV is a negative parity state



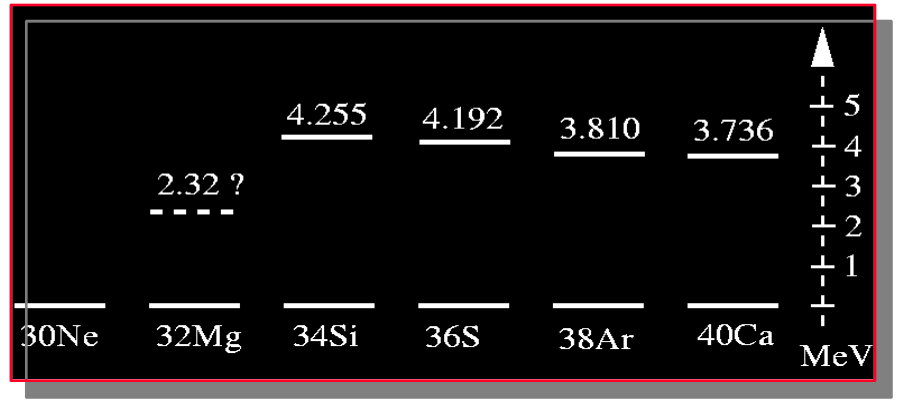
✓E345 : inelastic scattering : [W. Mittig et al.: EPJA 15, 157 (2002)]

^{32}Mg(^{28}Si,^{28}Si)^{32}Mg*. σ(2.32 MeV) is too high for 4^+.

σ(885 keV)/σ(2.3 MeV) is comparable to σ(2^+)/σ(3^-) in ^{34}Si.

	Eγ [MeV]	Ex [J^π]	σ_{pop} [mb]
^{34}Si	**3.33 (0.05)**	**3.326 [2+]**	**9.5 (2)**
	0.96 (0.05)	**4.255 [3-]**	**4.3 (1.5)**
^{32}Mg	**0.86 (0.05)**	**0.885 [2+]**	**40 (10)**
	1.44 (0.05)	**2.321 [?]**	**15 (5)**

Energy of 3$^-$ state in even-even N=20 nuclei



Search for the 0_2^+ state in ^{34}Si

✓**^{34}Al β-decay** [S.Numela et al., PRC63 (2001)044316]

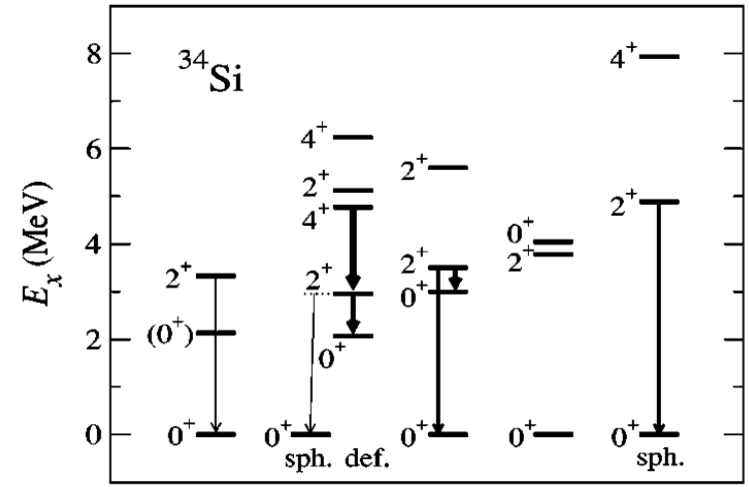
New γ-line @ 1.193MeV ($2_1^+ \rightarrow 0_2^+$) ?

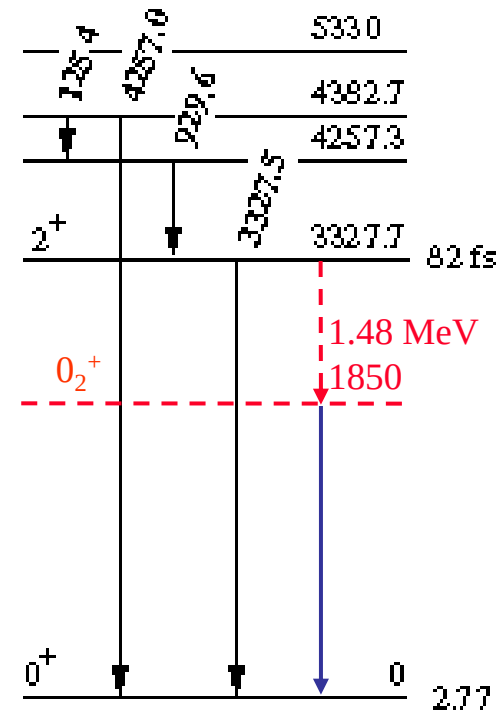
✓**In-beam γ-spectroscopy** [I.Iwasa et al., PRC67 (2003)064315]

1.193MeV: in coincidence with the $2^+ \rightarrow 0_1^+$
New γ-line 1.48 MeV: a possible candidate for the $2_1^+ \rightarrow 0_2^+$?

✓**E345:inelastic scattering** [W.Mittig et al., NPA722,10c (2003)., Prog.Theor.Phy. (Kyoto), Suppl 146,16 (2002).Eur. Phys. J. A15, 157 (2002)., Dimitri Baiborodim, Thesis.]

^{34}Si(^{28}Si,^{28}Si)^{34}Si* @ 50 MeV/n
Set for $E(0_2^+)<E(2^+)$
No significant events ($\sigma(0_2^+)<0.001\ \sigma_{th}$)
$\rightarrow 0_2^+$ may not lie below 2_1^+

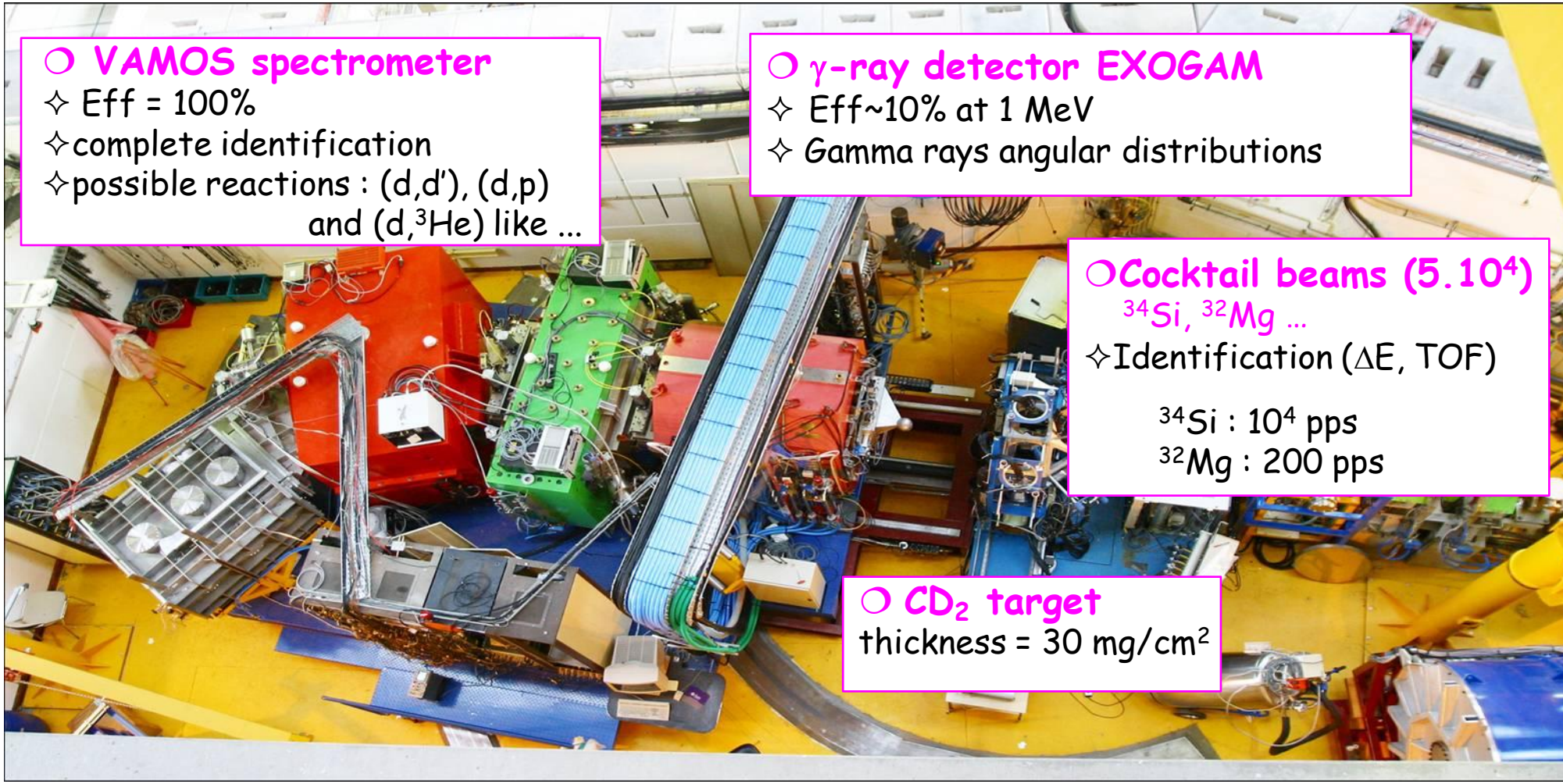




N. Iwasa et al. PRC**67** 064315 (2003)

$^{34}_{14}$Si

Detection system



❍ **VAMOS spectrometer**
- ✧ Eff = 100%
- ✧ complete identification
- ✧ possible reactions : (d,d'), (d,p) and (d,^{3}He) like ...

❍ **γ-ray detector EXOGAM**
- ✧ Eff~10% at 1 MeV
- ✧ Gamma rays angular distributions

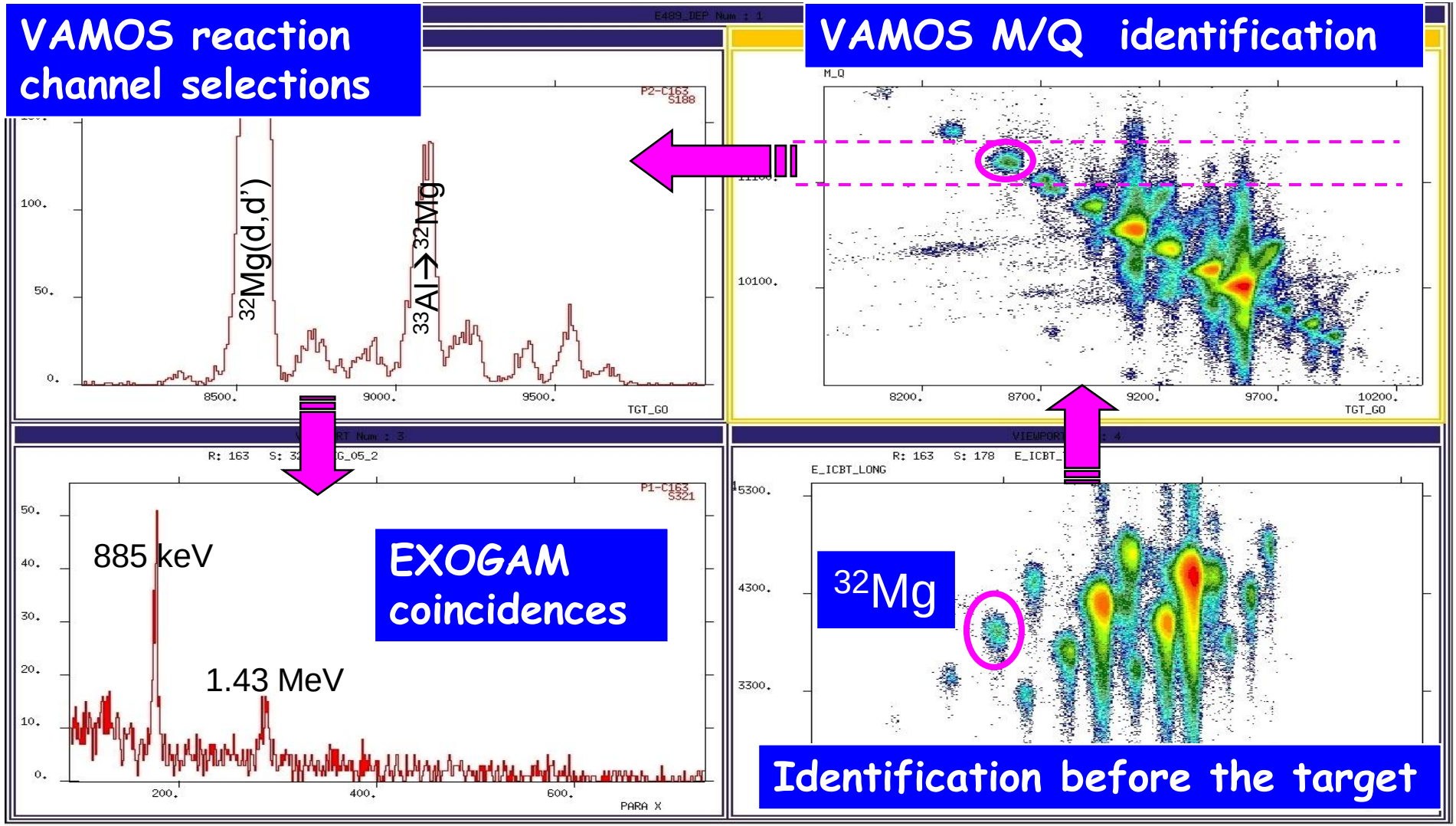
❍ **Cocktail beams (5.10^{4})**
^{34}Si, ^{32}Mg ...
- ✧ Identification (ΔE, TOF)

^{34}Si : 10^{4} pps
^{32}Mg : 200 pps

❍ **CD_2 target**
thickness = 30 mg/cm^{2}

VAMOS VARIABLE MODE SPECTROMETER + EXOGAM

Identification

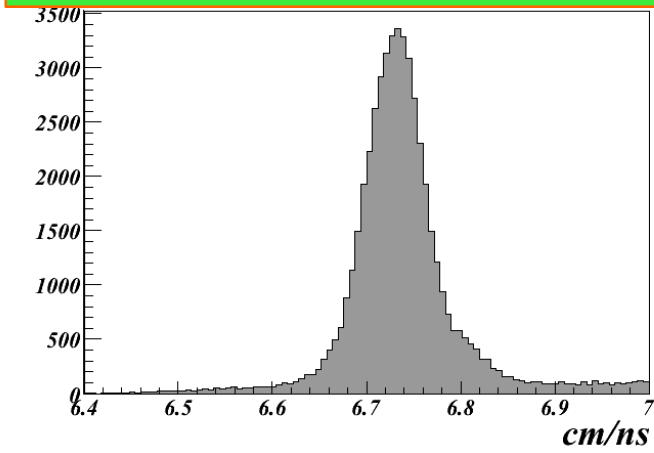


Several beams, several reaction channels

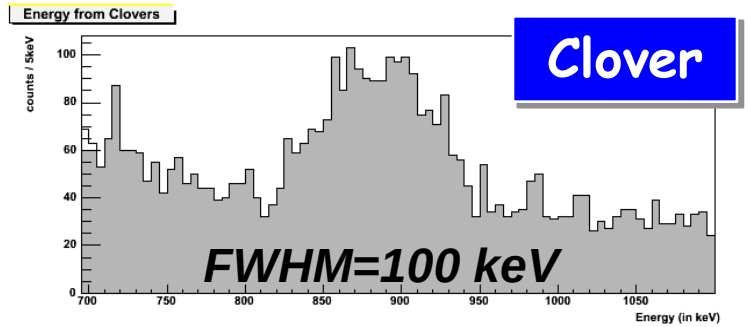
Gamma-ray detection : EXOGAM

- Energy from crystal
- Angle from GOCCE
  - * Doppler correction
  - *Angular distribution

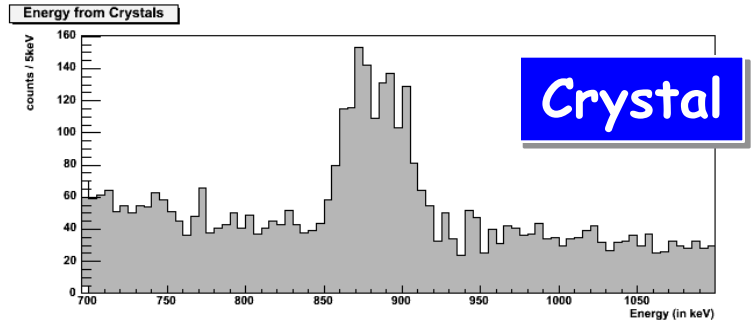
VAMOS :
➲ Recoil velocity (v ~ 6.8 cm/ns)



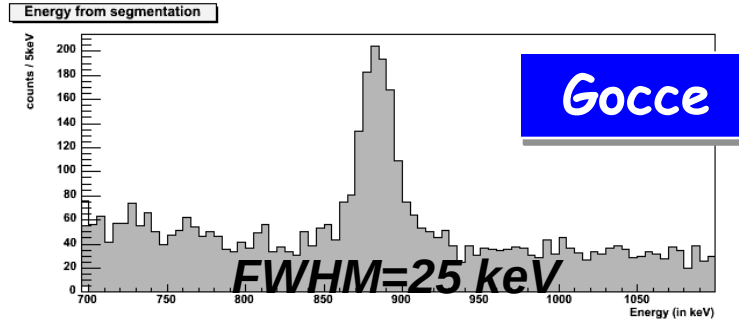
Doppler correction for 885 keV γ-ray in ^{32}Mg



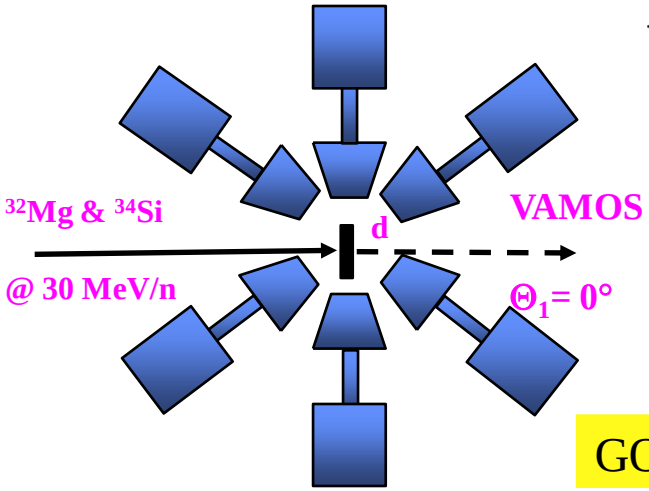
Clover

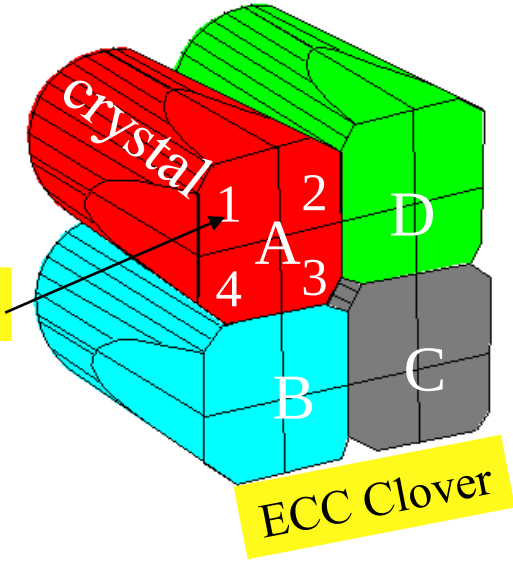


Crystal



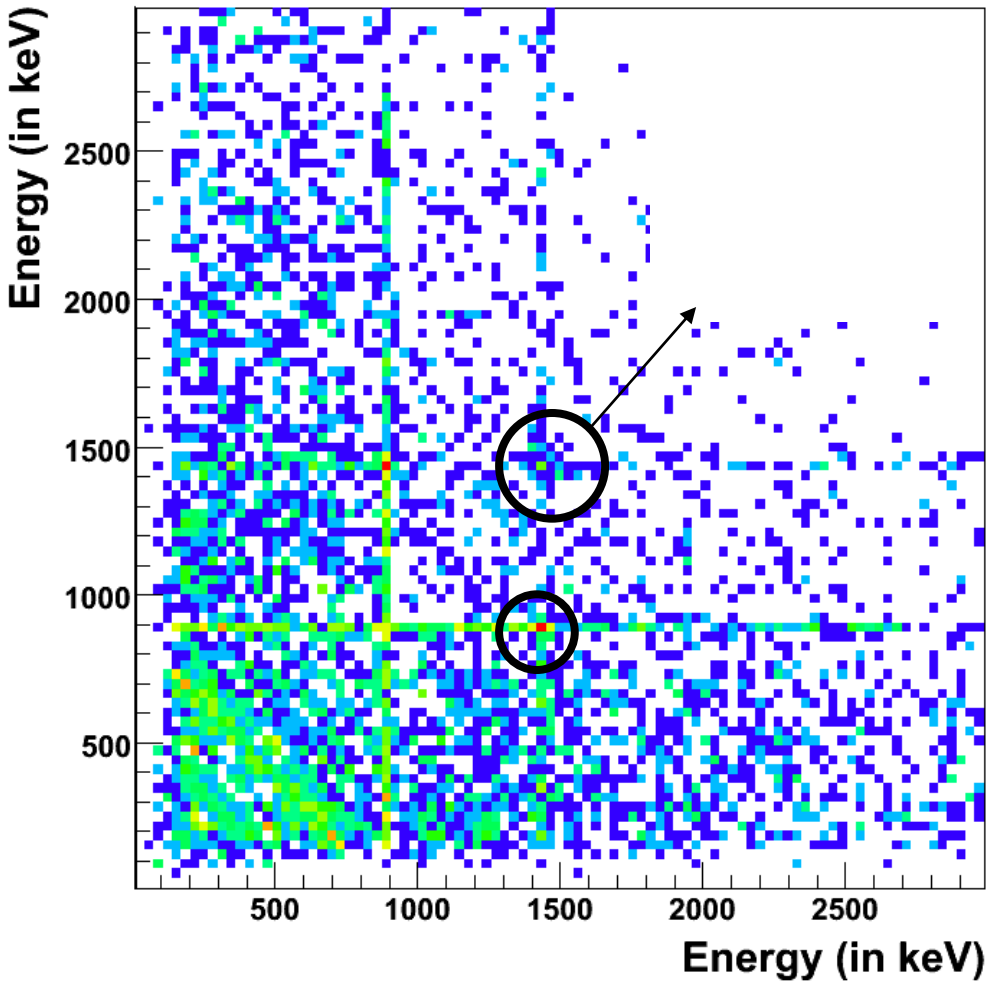
Gocce

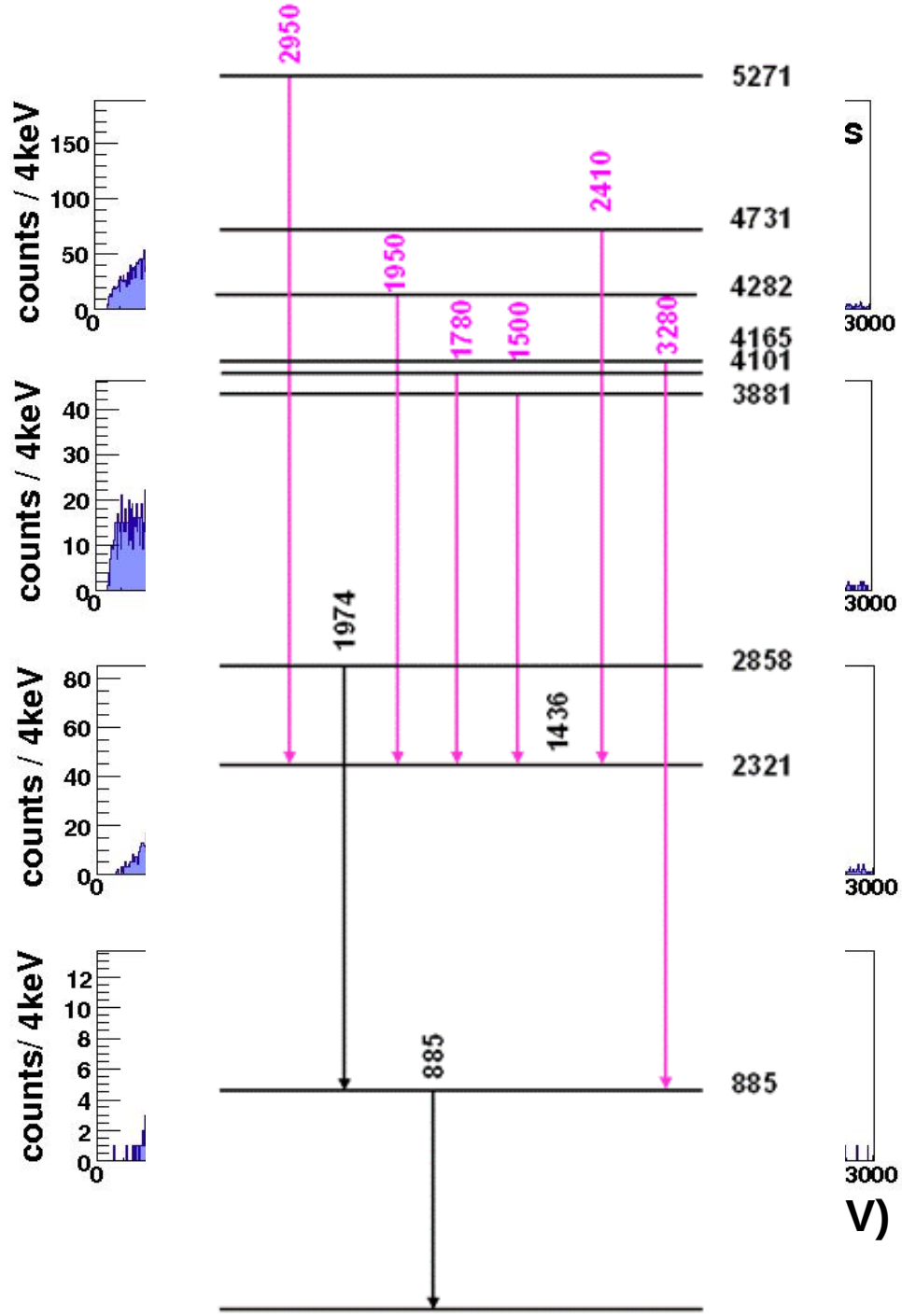




12 GOCCE rings:
Forward: 30^0, 40^0, 50^0, 60^0
Middle: 75^0, 85^0, 95^0, 105^0
Backward: 120^0, 130^0,140^0,150^0

^{32}Mg study



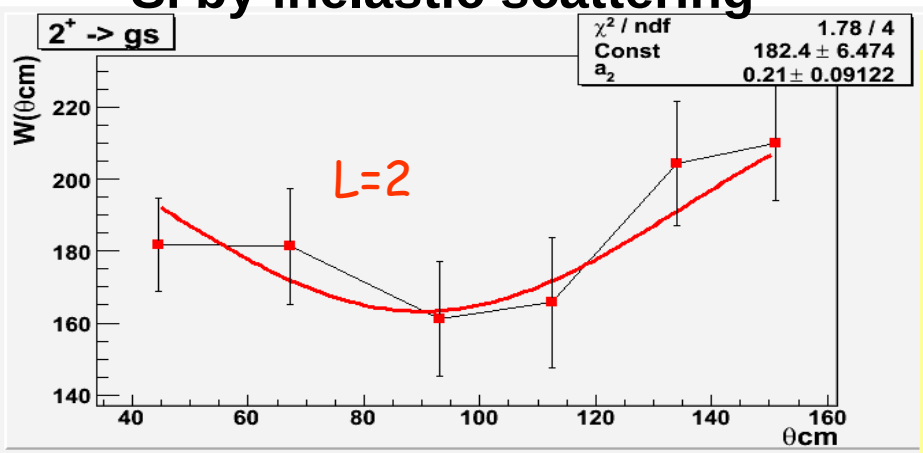


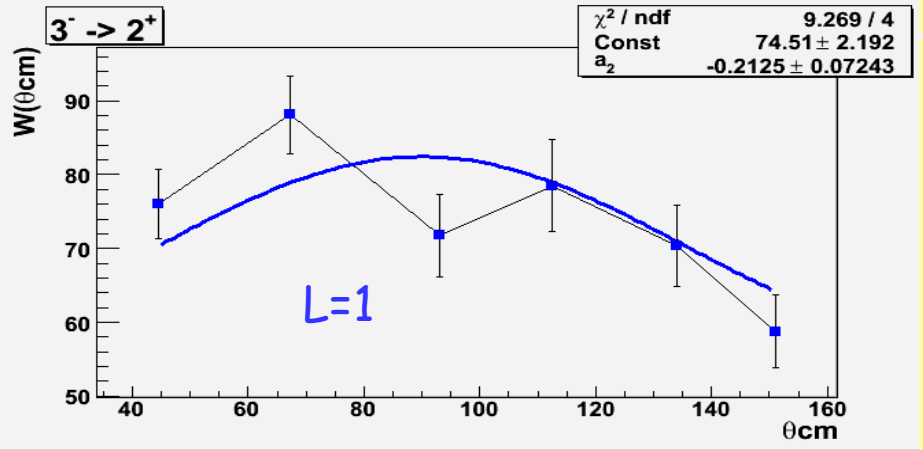
New : 2 transitions around 1430 keV

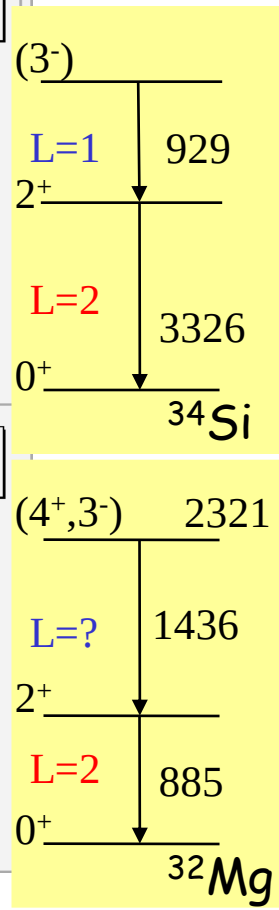
γ-ray angular distribution

$W(\theta) = Const[1+a_2P_2\cos(\theta)]$

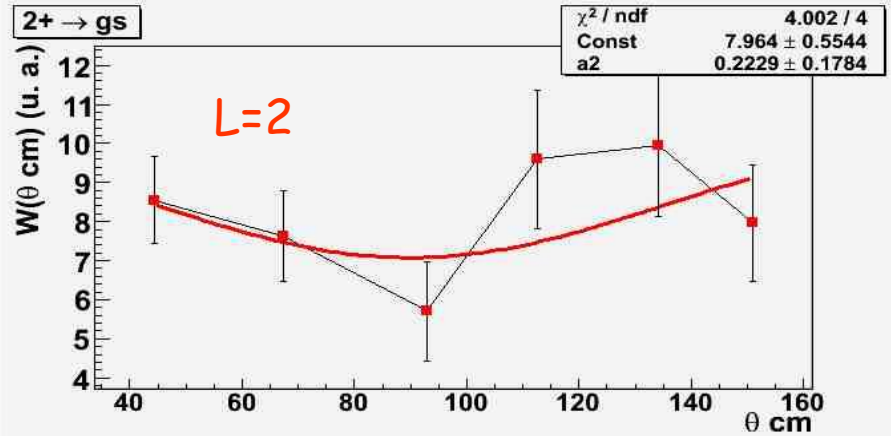
^{34}Si by inelastic scattering

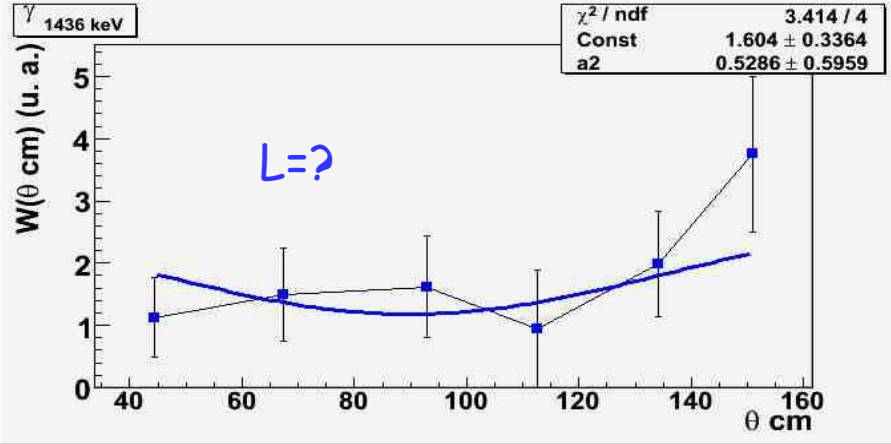






^{32}Mg by inelastic scattering

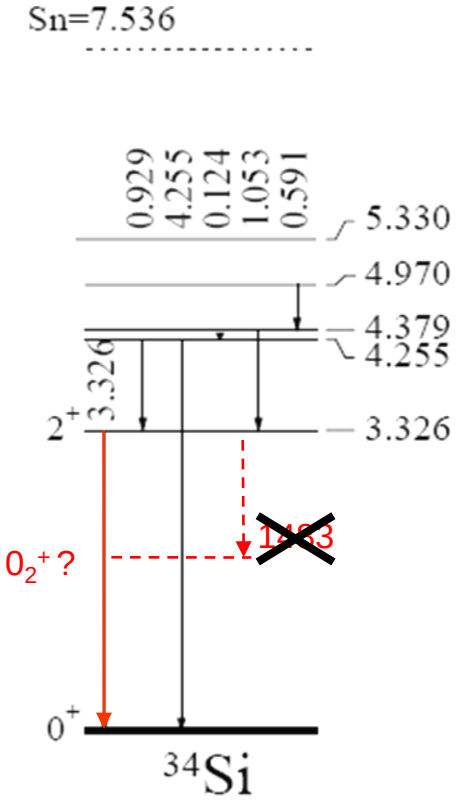




Firm assignment of 3^- in ^{34}Si at 4.2 MeV

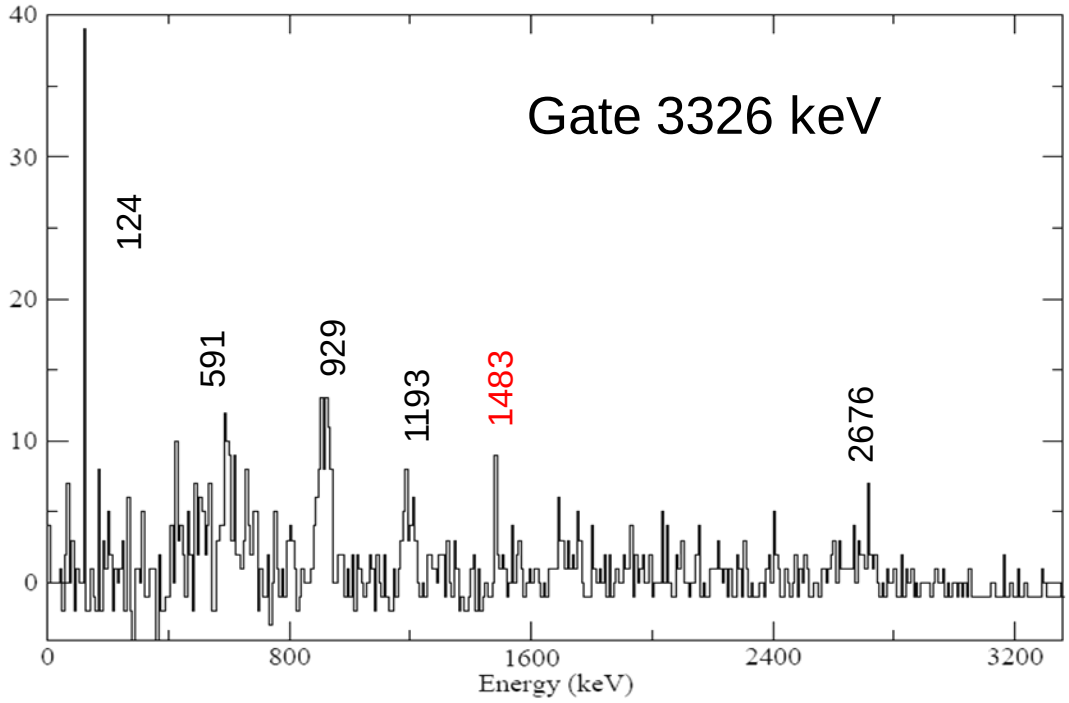
No clear conclusion on 1436 keV transition in ^{32}Mg

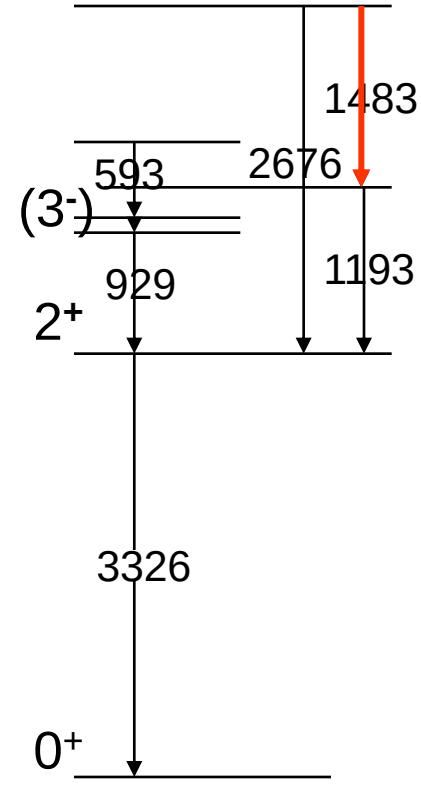
Search for the 0_2^+ state in ^{34}Si



N. IWASA et al. :
PRC 67, 064315 (2003)

γ–γ coincidence : ^{34}Si

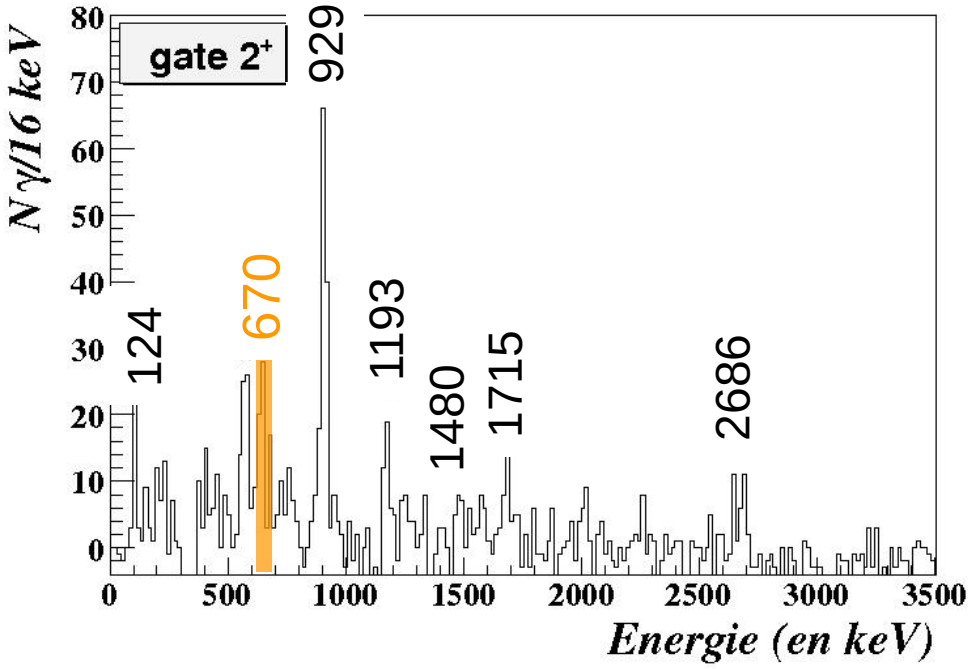


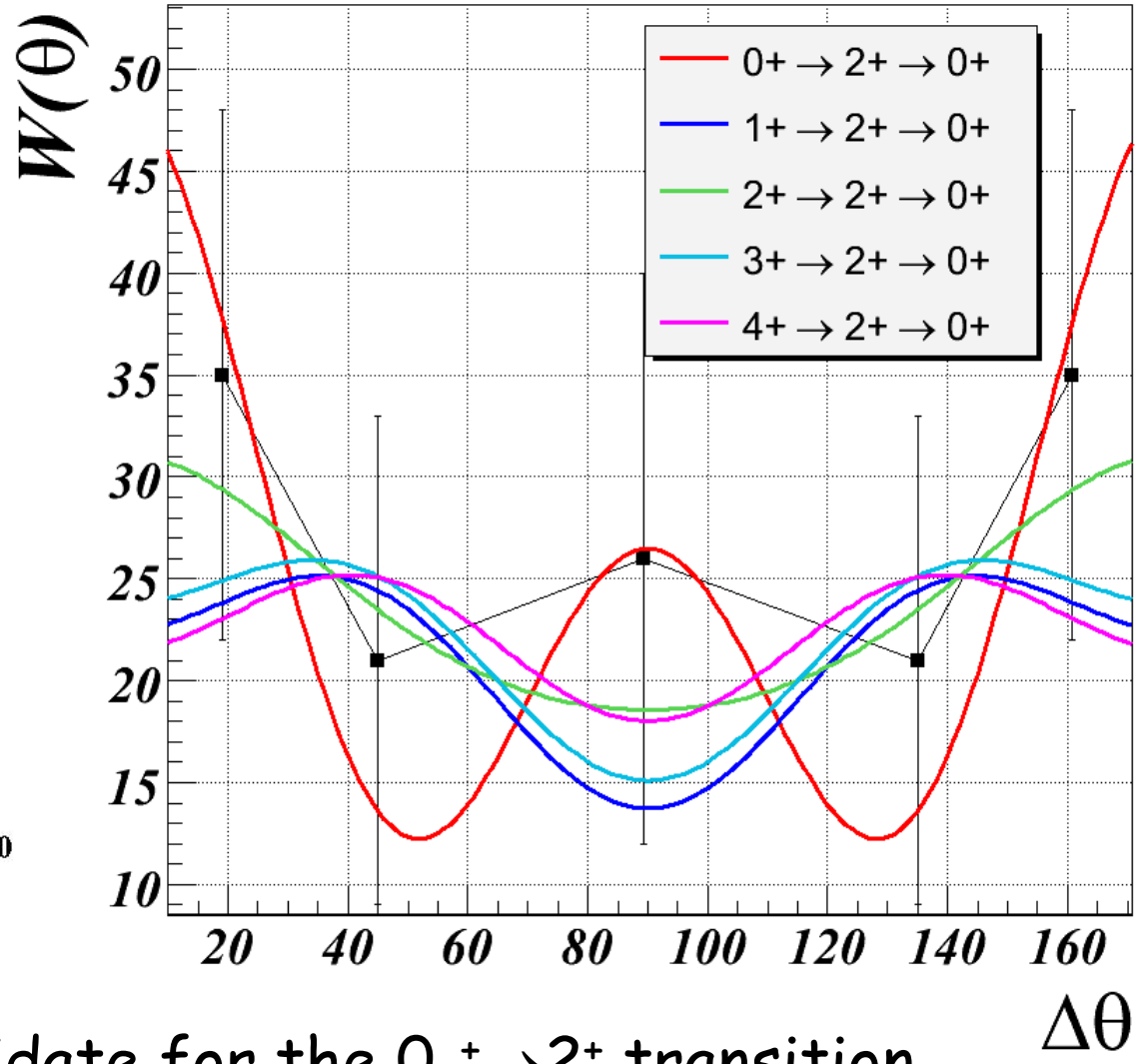


Present work

1483 keV is not the $2^+ \rightarrow 0_2^+$

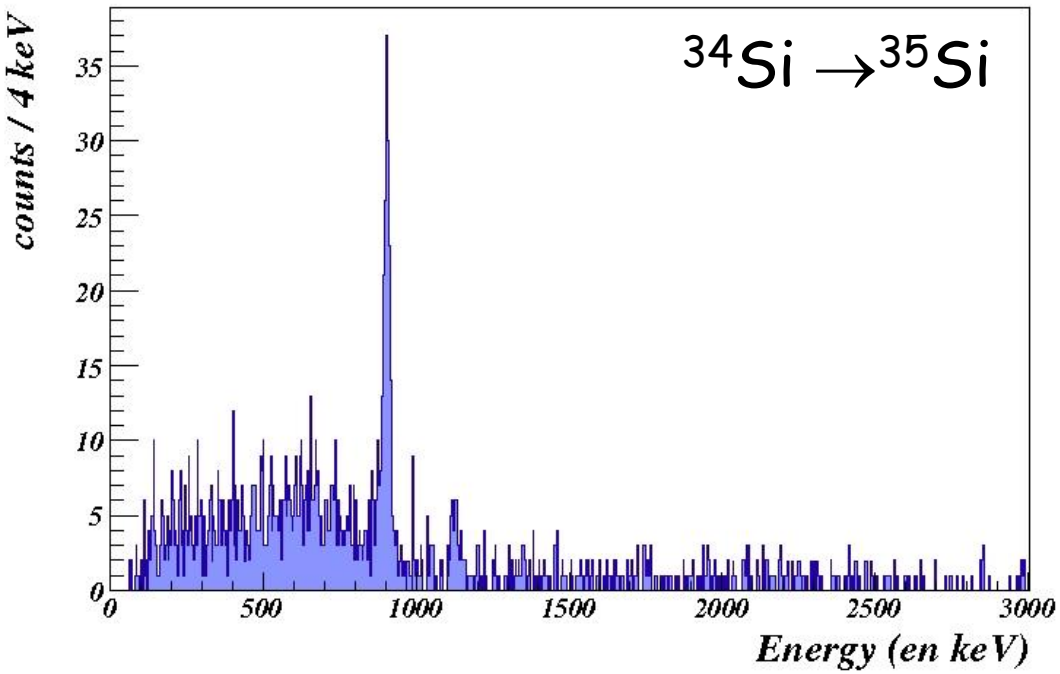
Search for the 0_2^+ state in ^{34}Si

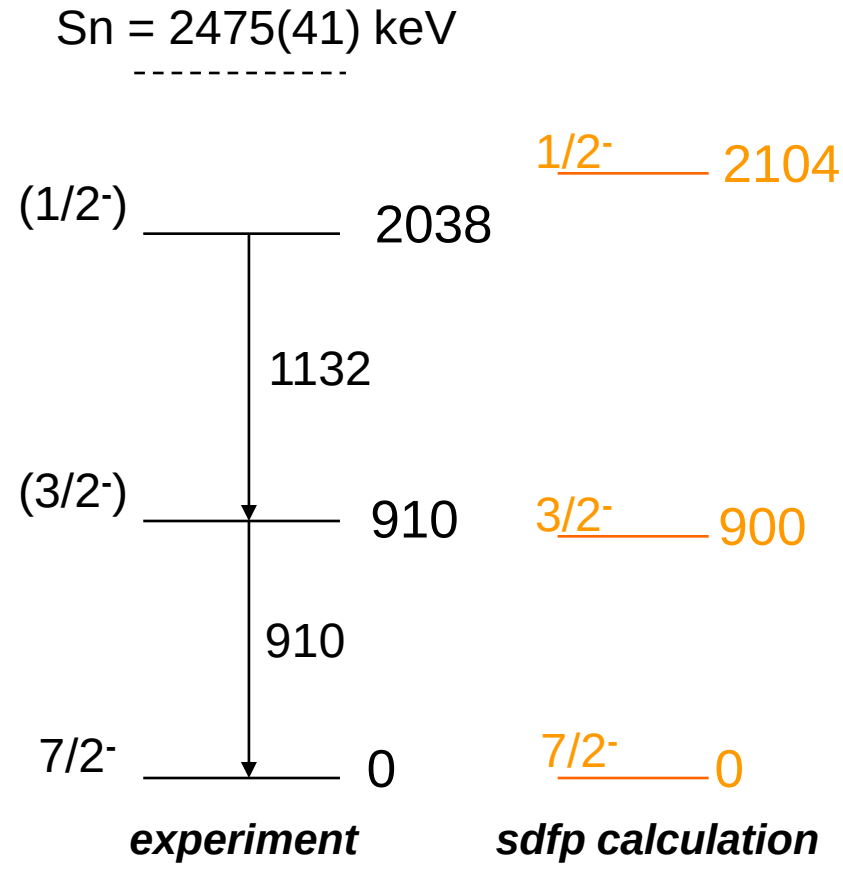




670 keV is a reasonable candidate for the $0_2^+ \rightarrow 2^+$ transition

Other nuclei : an example ^{35}Si





Conclusion

❖ VAMOS + EXOGAM is an excellent combination for spectroscopy with low intensity RIB

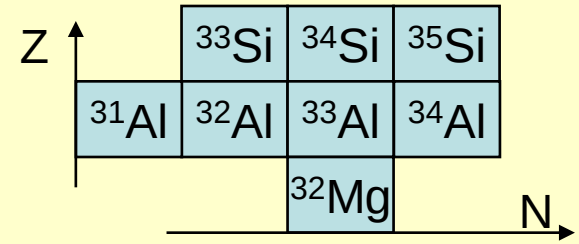
❖ GOCCE information (of EXOGAM) has been used effectively for Doppler correction and angular distribution

❖ Good γ -γ coincidence data help in unambiguous placement of levels.

❖ ^{32}Mg : doublet of levels around 1.4 MeV
2.3 MeV more in favour of a 4^+,

❖ ^{34}Si : 3^- assigned and new candidate for the 0_2^+ proposed at Ex=3.9 MeV

❖ New excited states in nuclei :



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