Gamma-ray spectroscopy with EXOGAM

G. de France, GANIL, for the EXOGAM collaboration

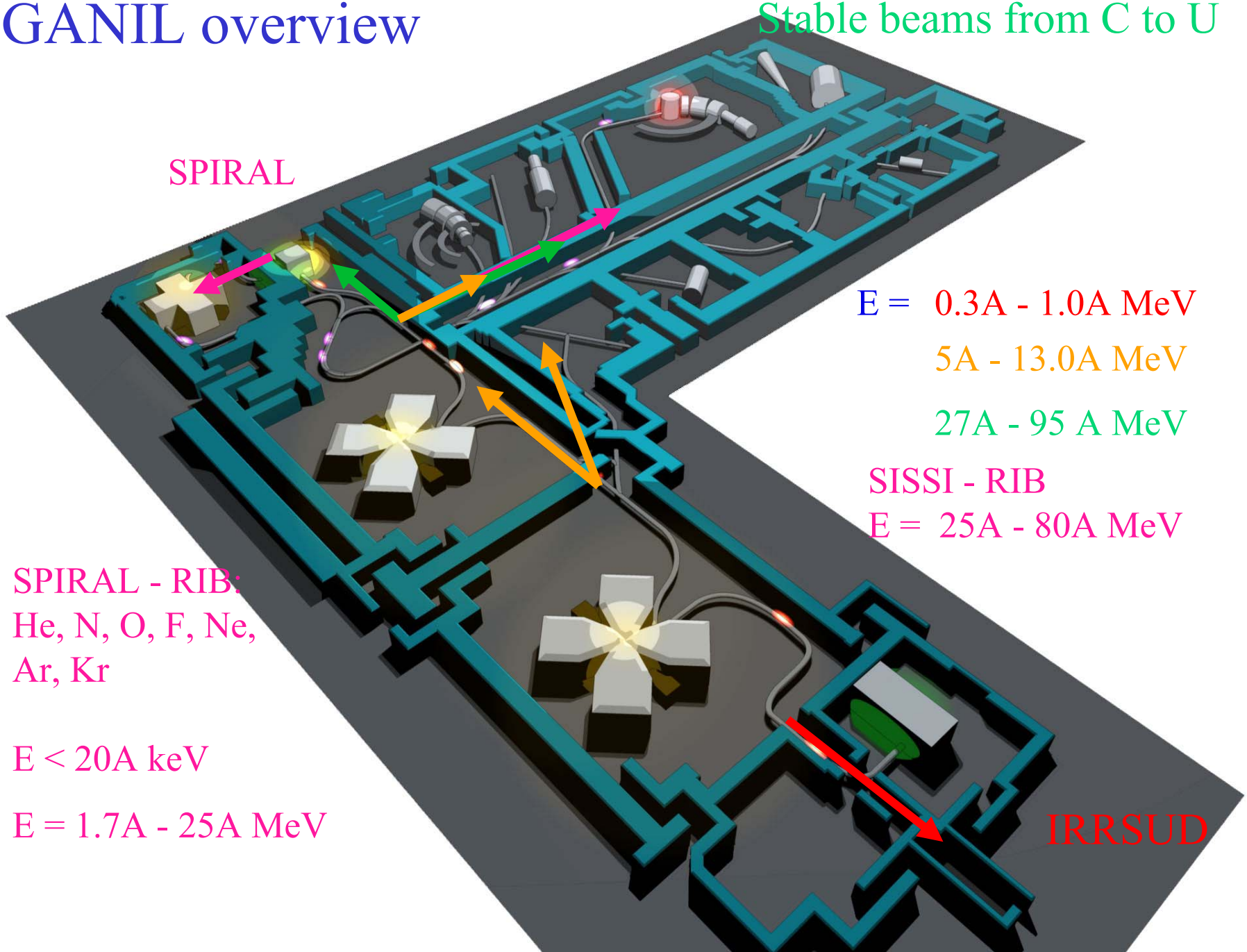
Gammapool workshop, Trento, May 8-12, 2006

Plan

- GANIL overview
- EXOGAM
- Physics examples
- Conclusions and outlook

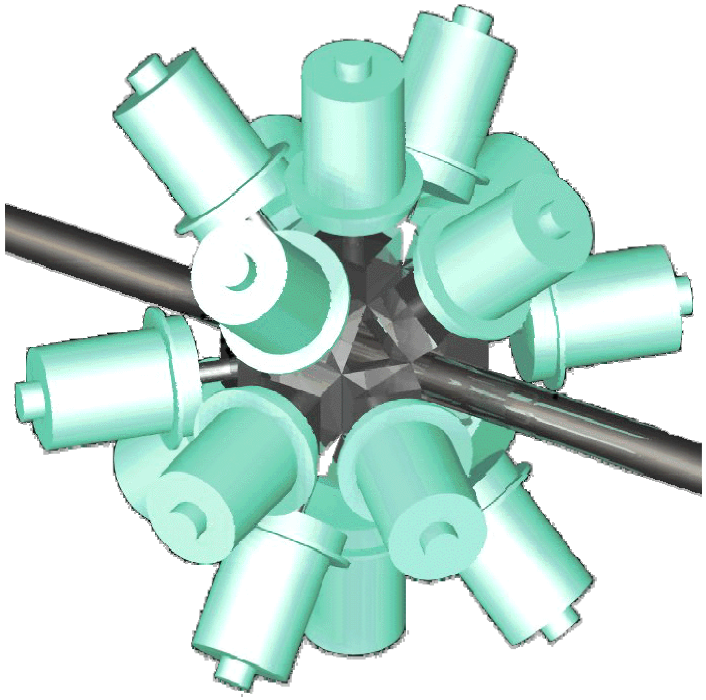
GANIL overview

Stable beams from C to U

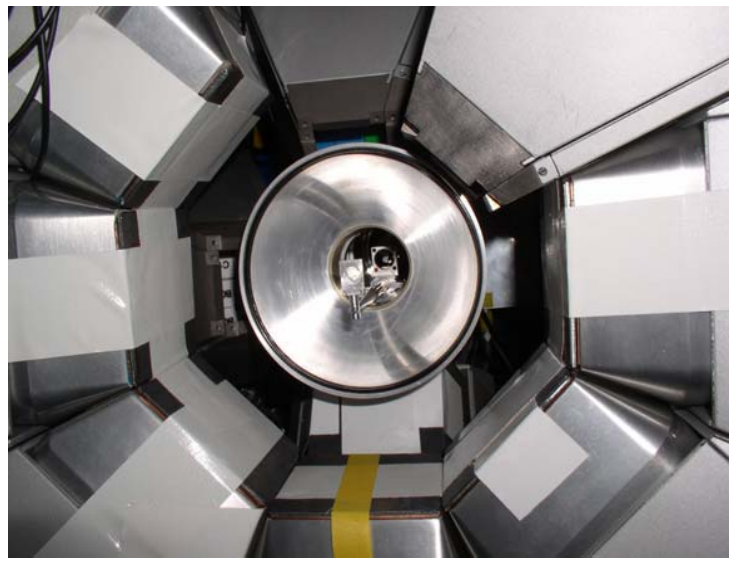


EXOGAM: High efficiency γ-spectrometer for exotic nuclei spectroscopy

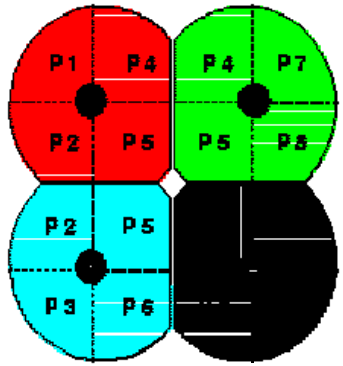
UK – France – Finland – Denmark – Hungary – Sweden - Germany



- Array for small and medium γ-ray multiplicity
- 20% efficiency @ 1.3 MeV
- Anti-Compton shield
- 16 segmented HPGe detectors
- Modularity
- Coupling with other detectors



The EXOGAM Clover



$^{86}Kr+^{12}C$, β=8.4%

Germanium type N

Resolution inner : 1.1 – 1.3 keV at 122keV

2.1 – 2.2 keV at 1.3 MeV

Resolution segment : 2.1 – 2.8 keV at 1.3 MeV

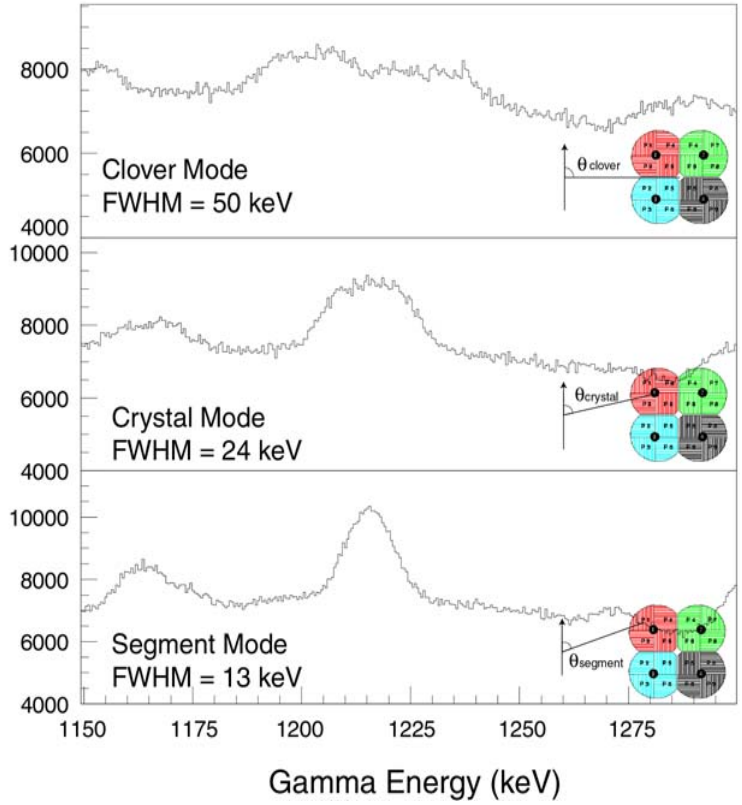
Rel. eff. : 40% x4 x1.5 (25cm, 1.3 MeV)

Abs. eff. : 1.7 10^{-3} x4 x1.5 (11.4cm, 1.3MeV)

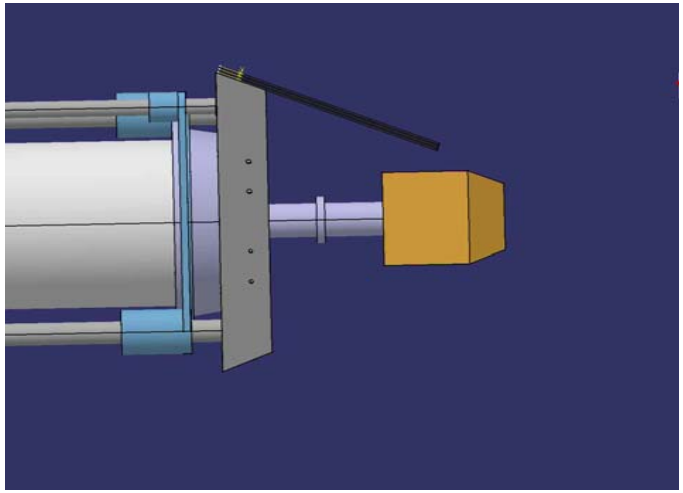
(~1% per detector)

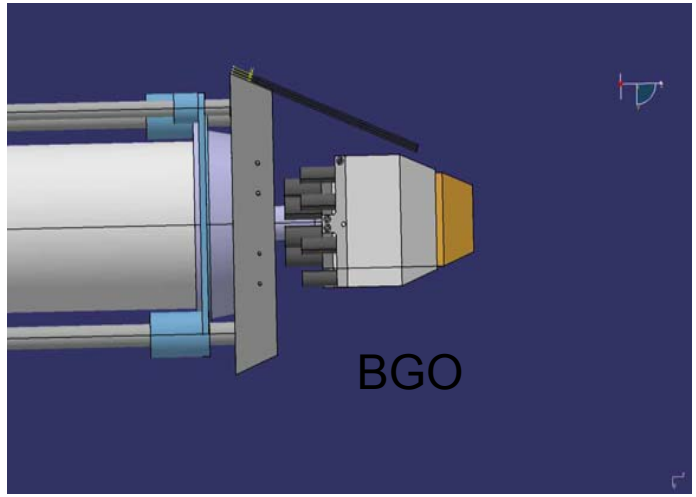
Timing < 6 ns

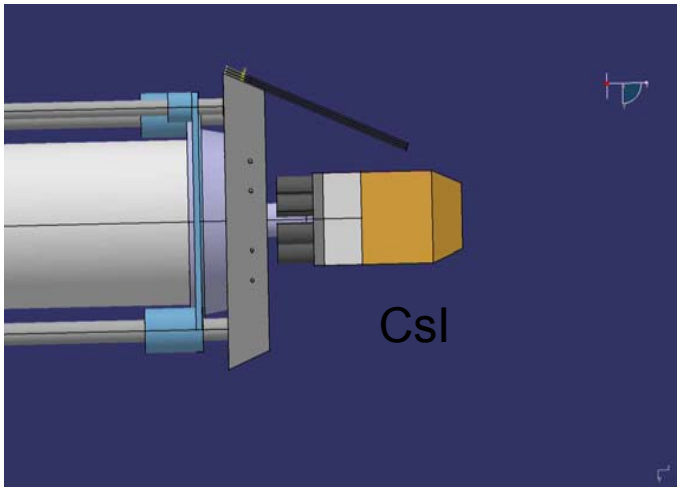
Preamplifier: 200 mV/MeV

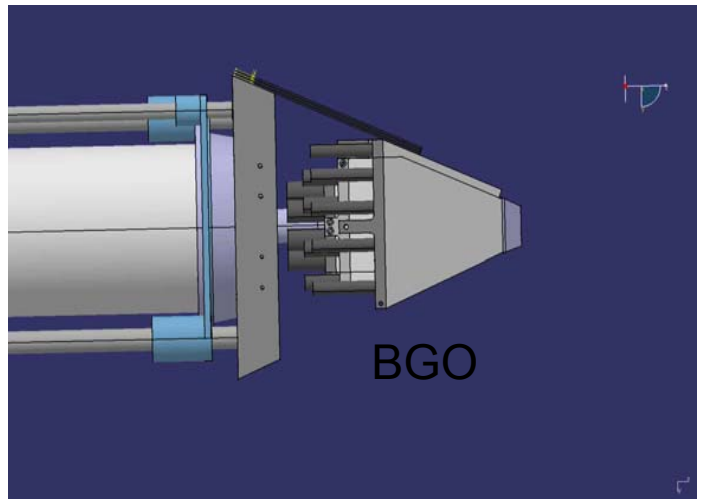


Anti-Compton Shield









Coupling with other detectors:

Campaigns with:

- EXOGAM+VAMOS
- EXOGAM+VAMOS+TIARA
- EXOGAM+Si CD
- EXOGAM+DIAMANT
- EXOGAM+DIAMANT+Nwall
- EXOGAM+SPEG
- …

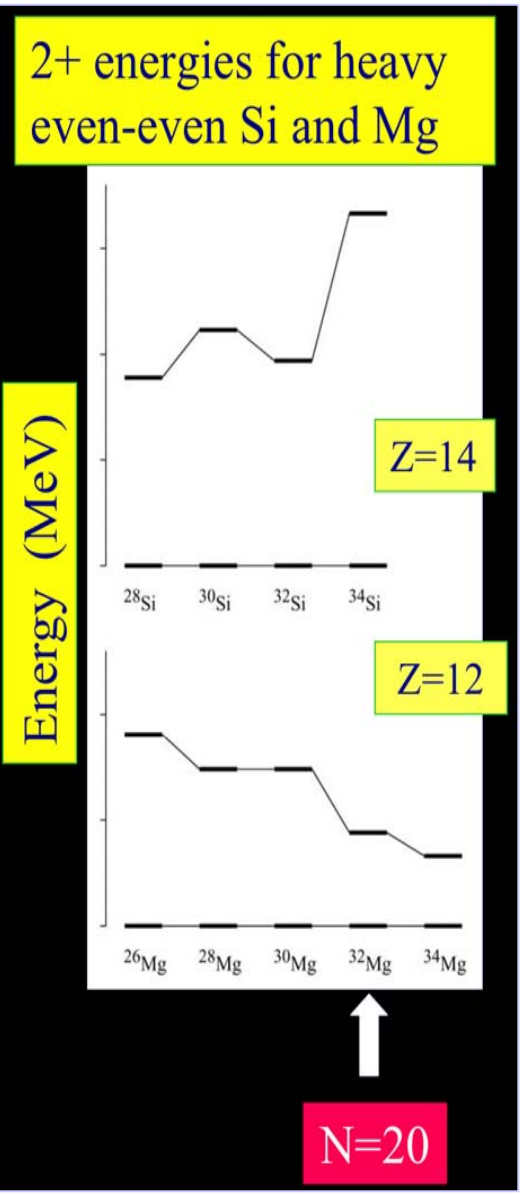
Physics with EXOGAM

- Spectroscopy of neutron rich nuclei around N=20
- Shape coexistence in Kr isotopes ➔A Goergen
- Gamma-ray spectroscopy of n-rich nuclei using deep-inelastic collisions ➔ S. Bhattacharyya
- RT and RDT with VAMOS and EXOGAM ➔ Ch Theisen
- In-beam gamma-ray spectroscopy at intermediate energy ➔ F Azaiez

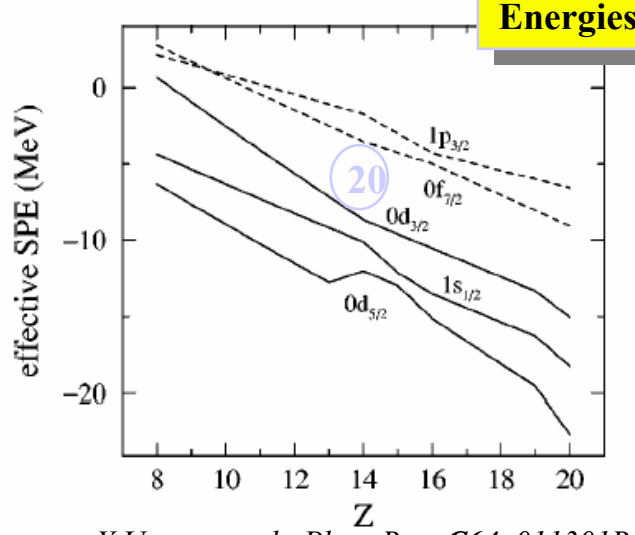
- *And many others!…*

Spectroscopy of neutron rich nuclei around N=20

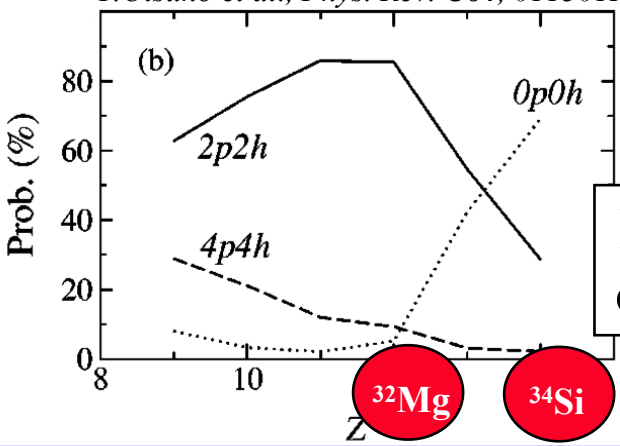
The N=20 shell closure



Effective single-particle Energies for N=20 isotones

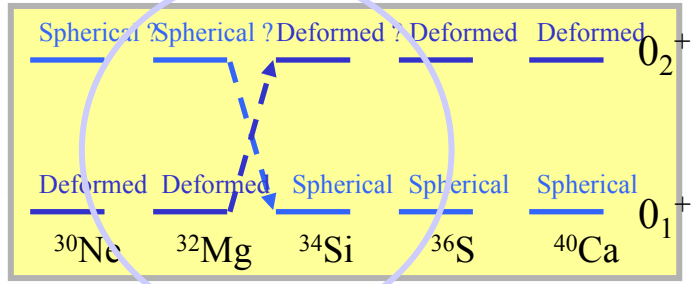


Y.Utsuno et al., Phys. Rev. **C64**, 011301R



Probabilities of np-nh configurations for N=20 isotones

Island of inversion



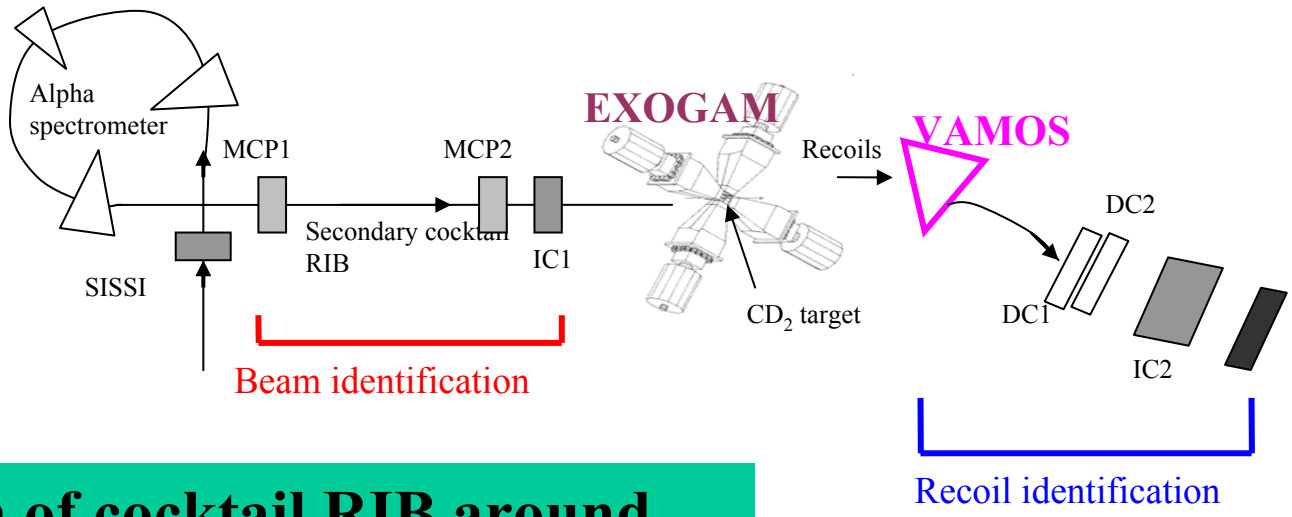
➢ Mixing of 0p-0h, 2p-2h configurations

Motivations

- Populates excited states in a number of nuclei and in particular low-lying 3^- states around ^{32}Mg.
  - ➔ Inelastic scattering / transfer reaction with cocktail RIB

- Search for the 0_2^+ in ^{34}Si
- Spectroscopy of odd-A nuclei
  - ➔ γ- γ coincidences

- Determine the multipolarity
  - ➔ Angular distribution of the γ-ray transitions



Production of cocktail RIB around ^{34}Si and ^{32}Mg:

Primary beam: ^{36}S (77 MeV/A)

Primary Target: ~ 1mg/cm^2 Ta (SISSI)

Selection: α- spectrometer

Energy: ~ 30 MeV/A

Population of the excited states in ^{32}Mg, ^{33}Al, ^{34}Si…:

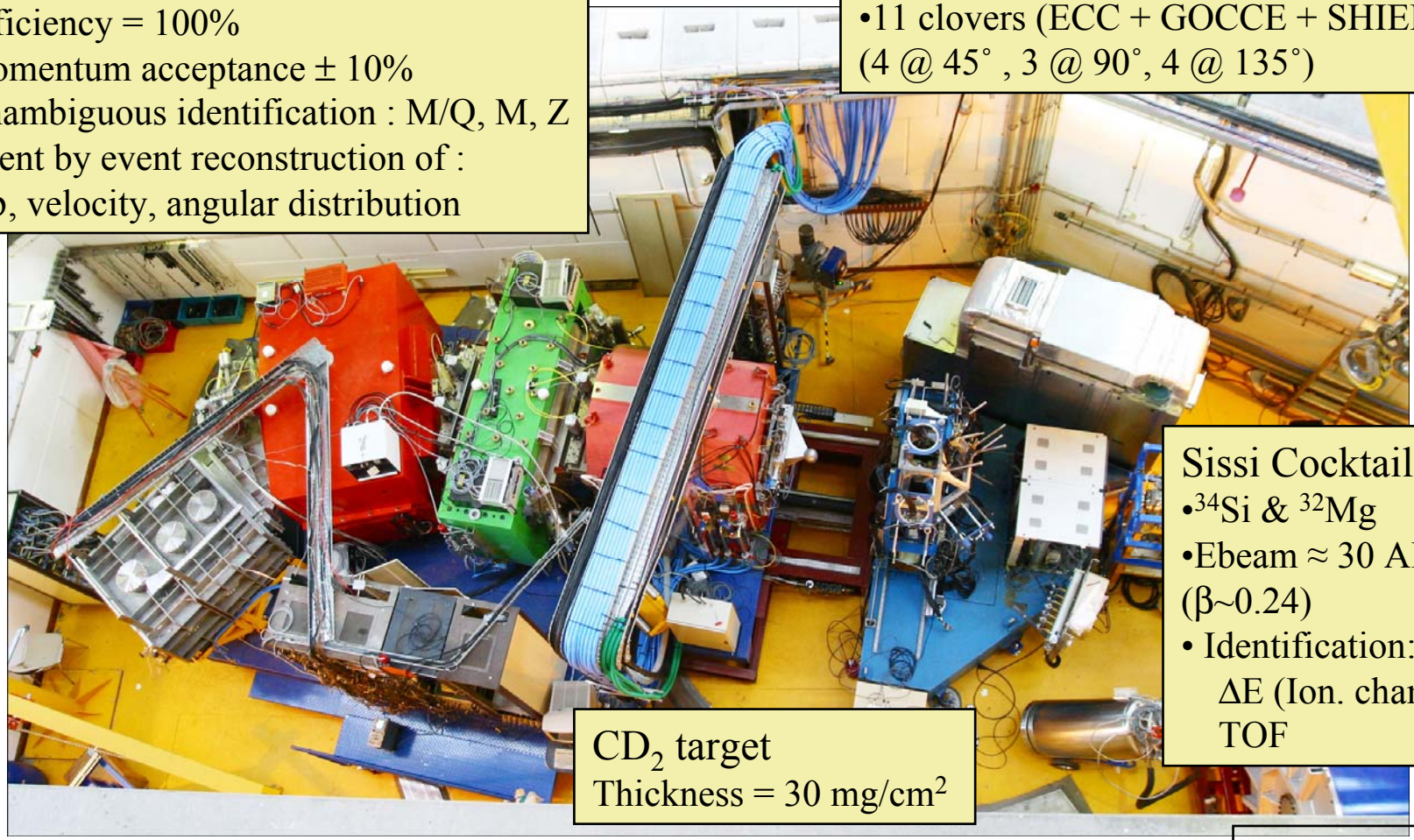
Target: CD_2 (30 mg/cm^2)

Mechanism: Reactions like (d,d'), (d,^{3}He), (d,t) …etc.

The setup

VAMOS spectrometer
- Efficiency = 100%
- Momentum acceptance ± 10%
- Unambiguous identification : M/Q, M, Z
- Event by event reconstruction of :
  Bρ, velocity, angular distribution

γ-ray spectrometer EXOGAM
- 11 clovers (ECC + GOCCE + SHIELD)
(4 @ 45° , 3 @ 90°, 4 @ 135°)



Sissi Cocktail beams
- ^{34}Si & ^{32}Mg
- Ebeam ≈ 30 AMeV (β~0.24)
- Identification:
  ΔE (Ion. chamber)
  TOF

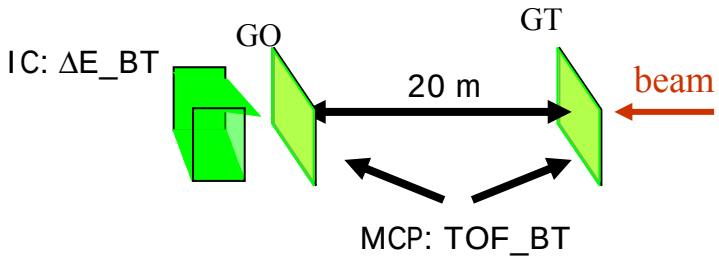
CD_2 target
Thickness = 30 mg/cm^2

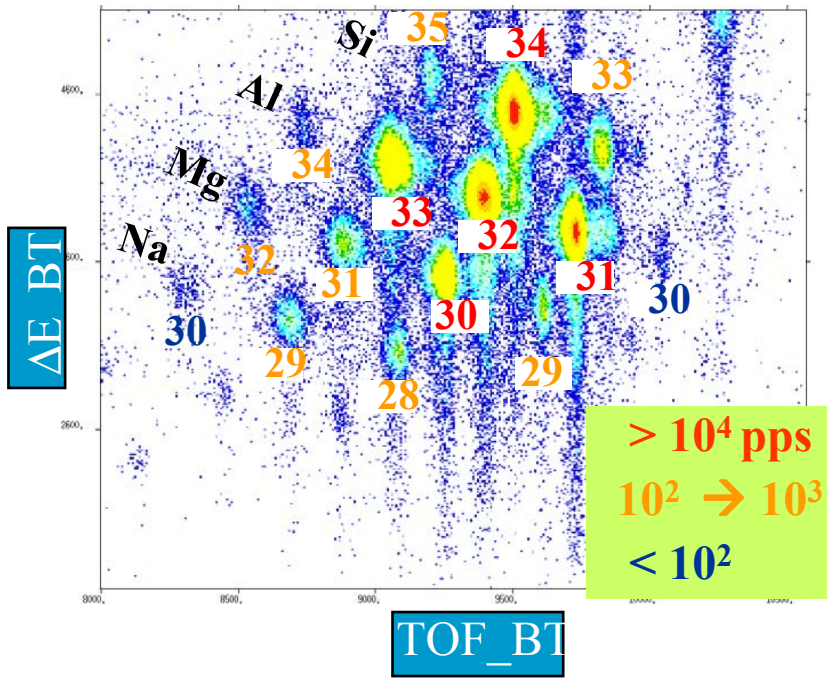
VAMOS VARIABLE MODE SPECTROMETER

H. Savajols, M. Gelin, G. Mukherjee et al.

EXOGAM

Beam Identification



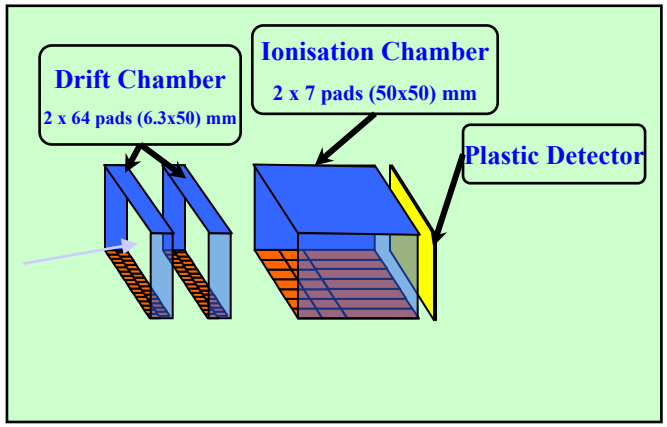


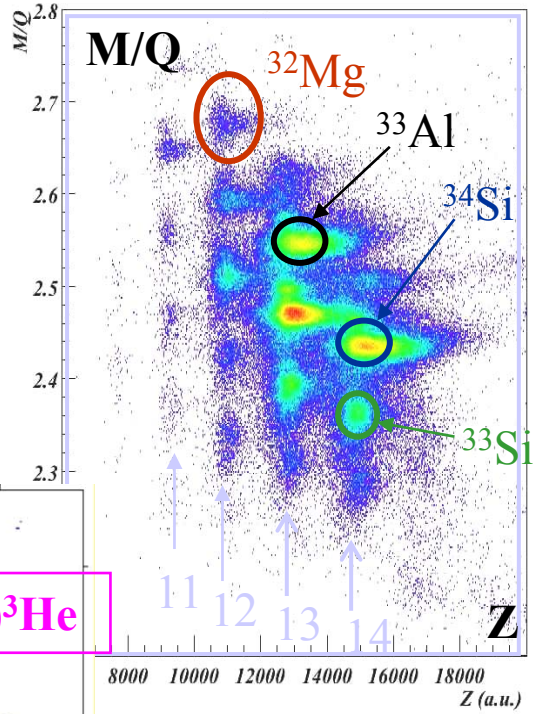
15	P 27 0.26s	P 28 0.2703s	P 29 4.14s	P 30 2.498m	P 31 100	P 32 14.26d	P 33 25.34d	P 34 12.43s	P 35 47.3s	P 36 5.6s	P 37 2.31s
14	Si 26 2.234s	Si 27 4.16s	Si 28 92.2297	Si 29 4.6832	Si 30 3.0872	Si 31	Si 32	Si 33 6.18s	Si 34 2.77s	Si 35 0.78s	Si 36 0.45s
13	Al 25 7.183s	Al 26 7.4e+05y	Al 27 100	Al 28 2.241m	Al 29 6.56m	Al 30 3.6s	Al 31 0.644s	Al 32 0.033s	Al 33 0.2s	Al 34	Al 35 0.0386s
12	Mg 24 78.99	Mg 25 10	Mg 26 11.01	Mg 27 9.458m	Mg 28 20.91h	Mg 29 1.3s	Mg 30 0.335s	Mg 31 0.23s	Mg 32 0.12s	Mg 33 0.09s	Mg 34 0.02s
11	Na 23 100	Na 24 14.96h	Na 25 59.1s	Na 26 1.072s	Na 27 0.301s	Na 28 0.0305s	Na 29 0.0449s	Na 30 0.048s	Na 31 0.017s	Na 32 0.0132s	Na 33 0.0082s
10	Ne 22 9.25	Ne 23 37.24s	Ne 24 3.38m	Ne 25 0.602s	Ne 26 0.23s	Ne 27 0.032s	Ne 28 0.019s	Ne 29 0.0156s	Ne 30 0.0058s	Ne 31 0.0034s	Ne 32 0.0035s
9	F 21 4.158s	F 22 4.23s	F 23 2.23s	F 24 0.34s	F 25 0.05s	F 26 0.0096s	F 27 0.0052s		F 29 0.0024s		F 31 0.00112s
8	O 20 13.51s	O 21 3.42s	O 22 2.25s	O 23 0.082s	O 24 0.065s		O 26 0.00568s				

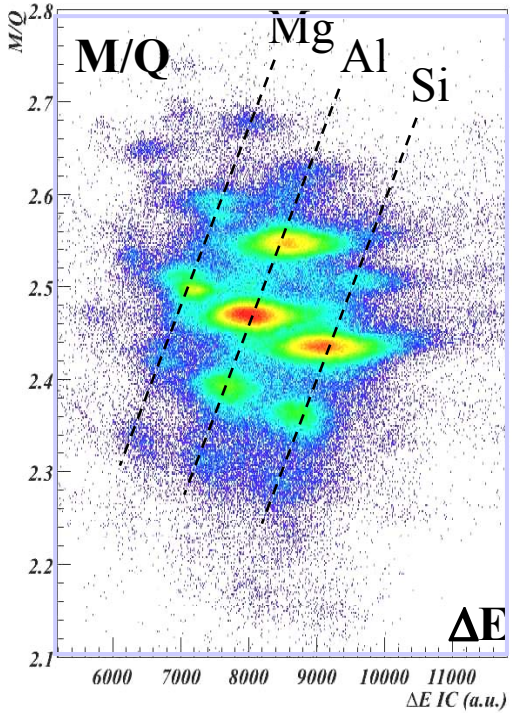
Z

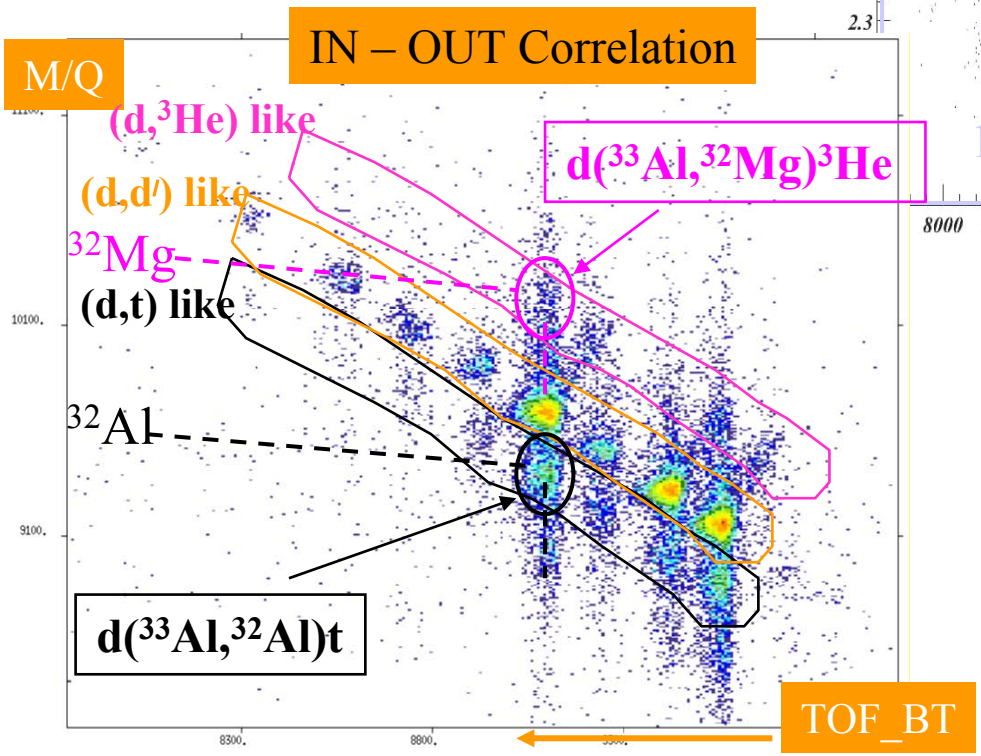
N

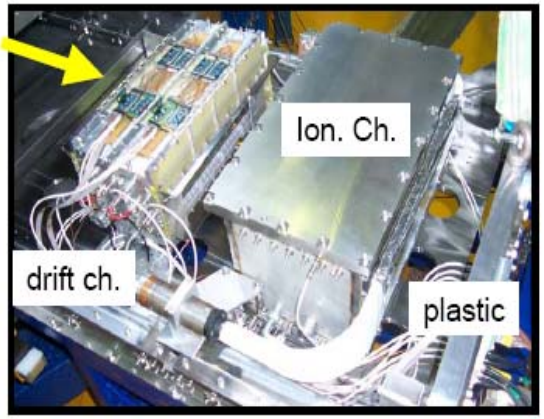
Recoil Identification





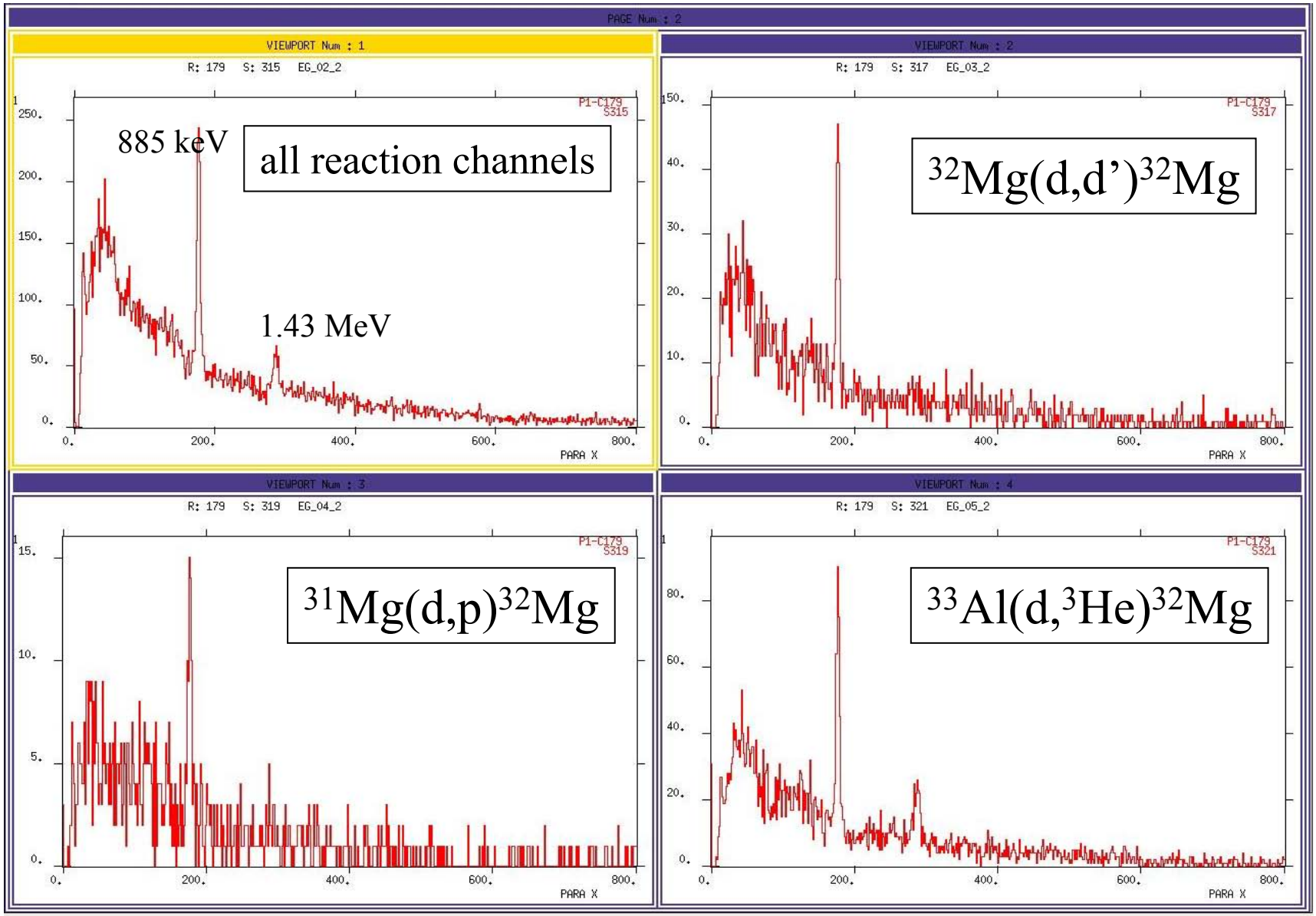






Spectroscopy of neutron rich nuclei around N=20

Online results



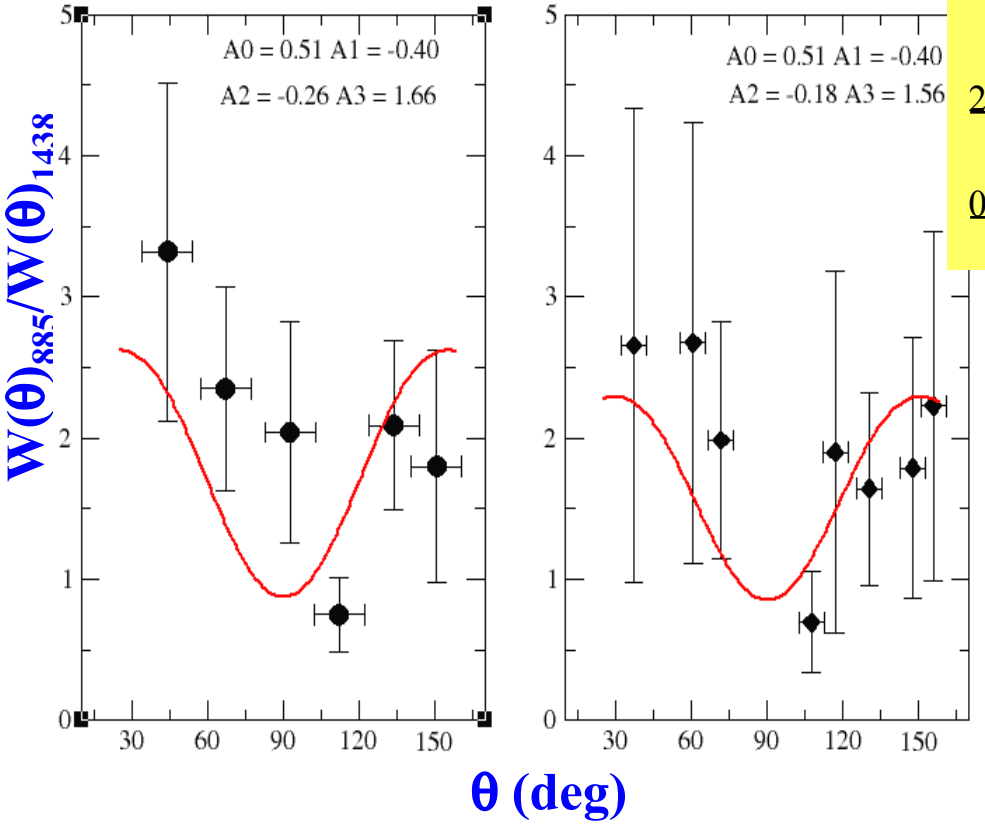
Preliminary Results

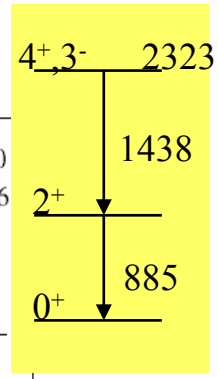
γ-ray Angular distribution: ^{32}Mg from (d,^{3}He) like reaction

$W(\theta)_{L=2} = A_0[1+A_2P_2\cos(\theta) + A_4P_4\cos(\theta)]$
$A_2 = 0.5$, $A_4 = -0.37$

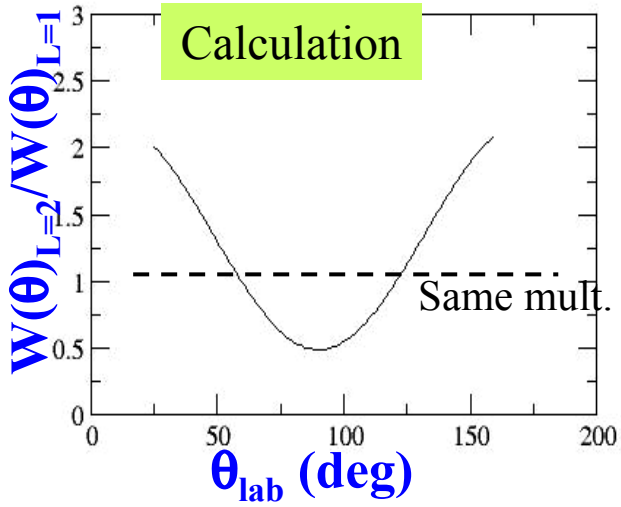
$W(\theta)_{L=1} = A_0[1+A_2P_2\cos(\theta)]$
$A_2 = -0.5$

Present experiment





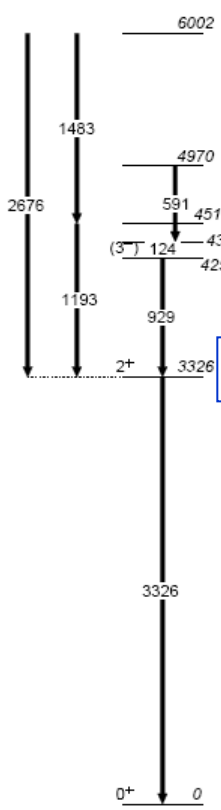
Calculation



2.3 MeV state is a 3^{-} ?!

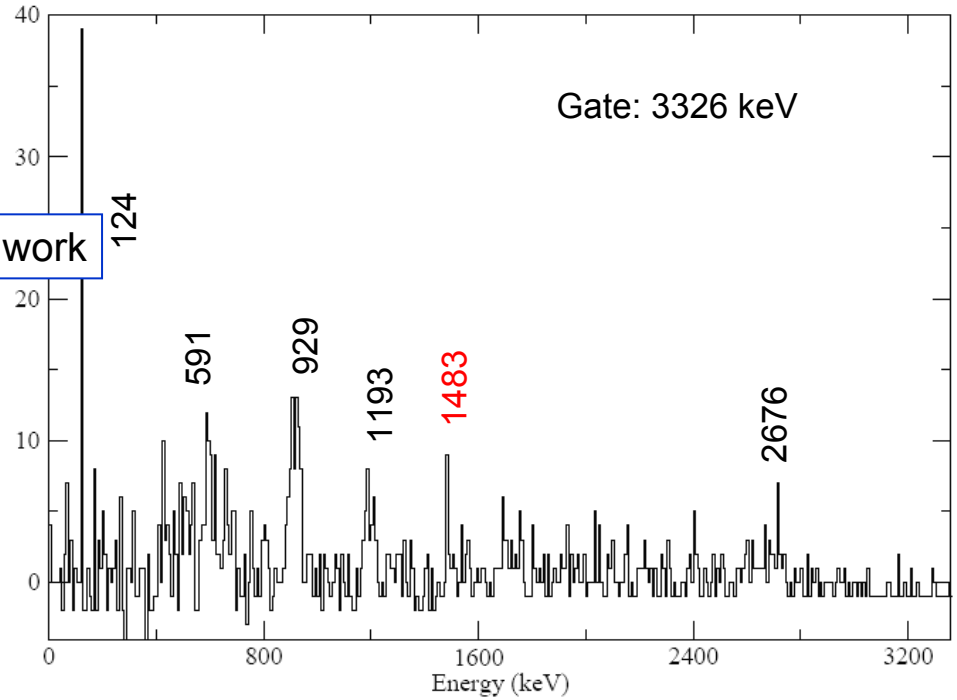
G. Mukherjee, M. Gelin et al.

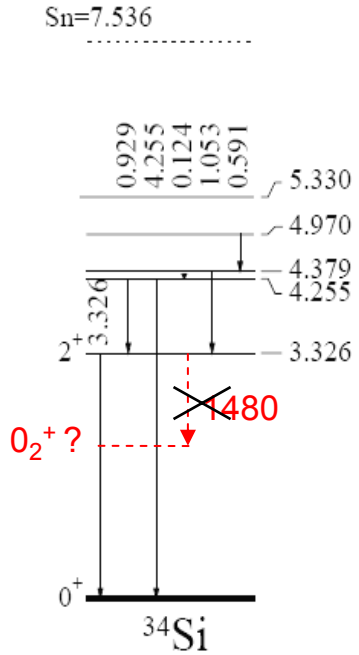
Preliminary Results



^{34}Si

Present work

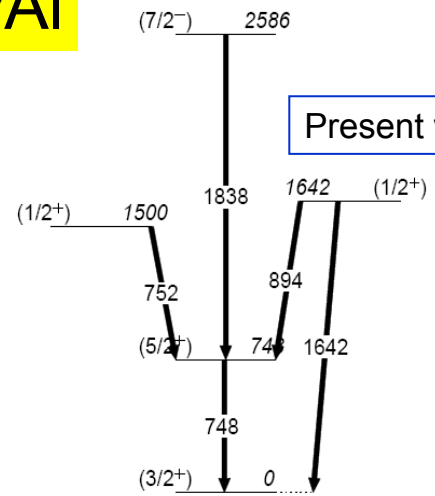




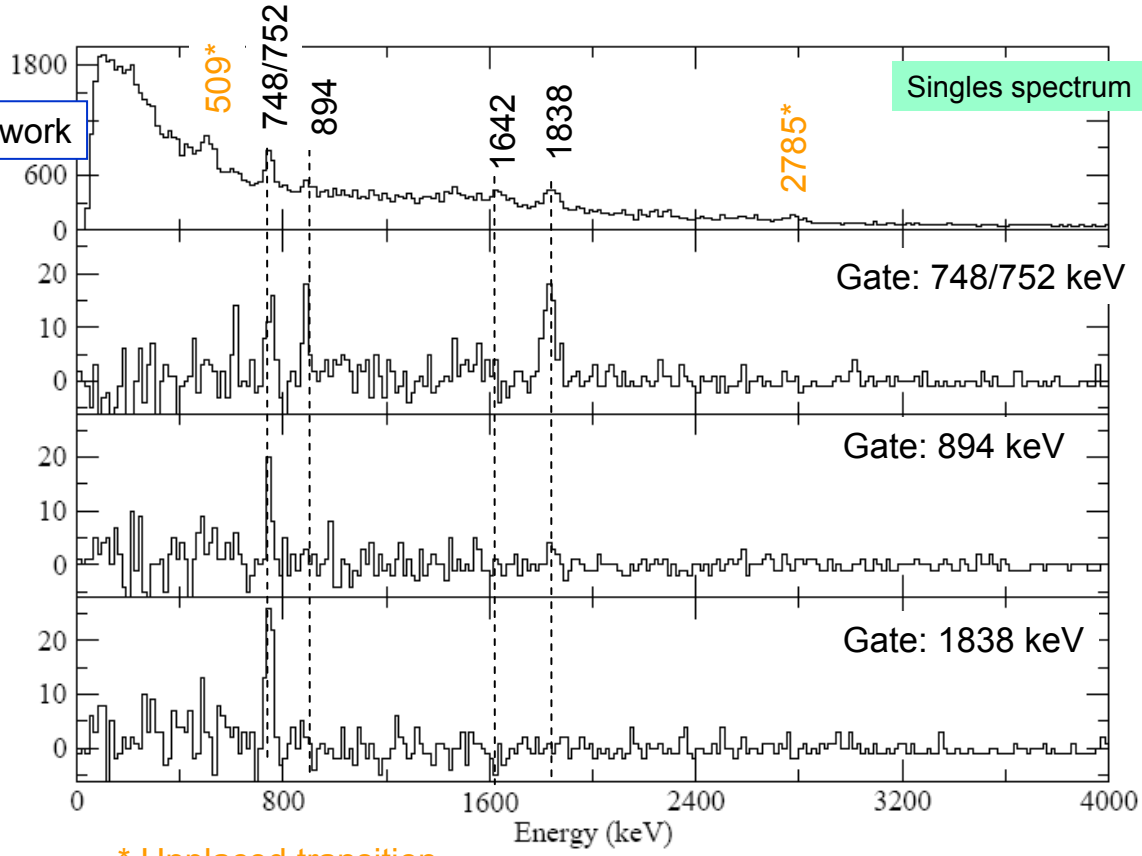
N. IWASA et al. : PRC 67, 064315 (2003)

Preliminary Results

^{33}Al



Present work



* Unplaced transition

730±50

W. Mittig et al.: EPJA 15, 157 (2002)

Conclusions & Outlook

- EXOGAM is heavily used at GANIL
- The physics case addressed by EXOGAM (most of the time in combination with other detectors) is very large
- The setup of an experiment using a radioactive beam is tricky
- We need to improve the counting rate capabilities of EXOGAM AND the ancillaries associated to it!
- EXOGAM+AD at GANIL