



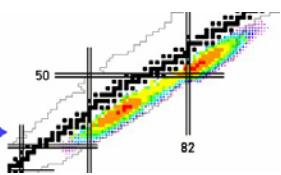
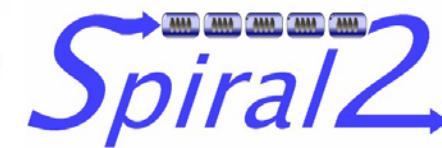
High Resolution γ -Spectroscopy at SPES and SPIRAL2

A. Gadea (IFIC Valencia, Spain)

on behalf of the HRGS community

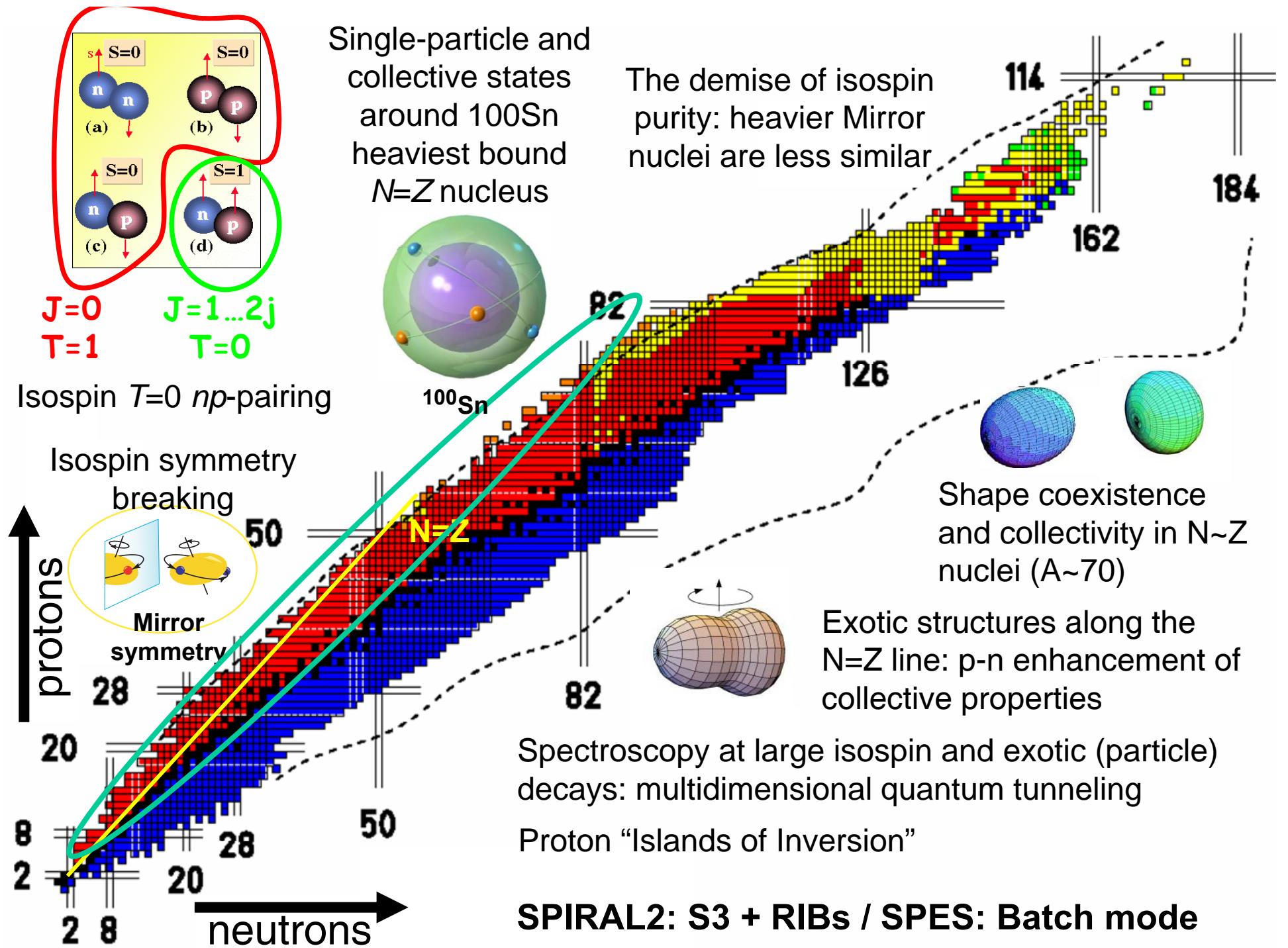
IV LEA-COLLIGA Meeting

November 18th-19th, 2010 – Laboratory Nazionali di Legnaro



Physics Case, Lols for SPIRAL2 and SPES:

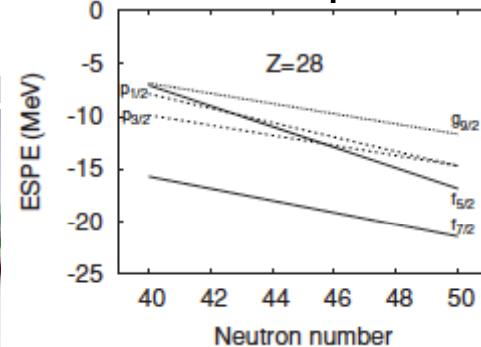
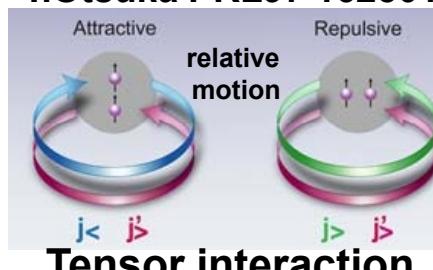
- Nuclei in the vicinity of $N=Z$ (Symmetric nuclear matter)
- Shell structure and the isospin degree of freedom (Changing shell structure)
- Collective response of nuclei
- Structure of the Nuclei at High Spin
- Shape coexistence, phase transitions and dynamical symmetries
- Structure of Heavy and SuperHeavy Nuclei



Structure of neutron-rich nuclei

- Evolution of the shell structure far from stability; single particle levels and shell gaps Evolution of shapes and collectivity

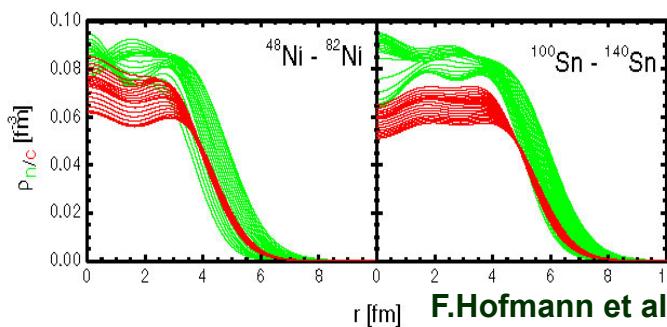
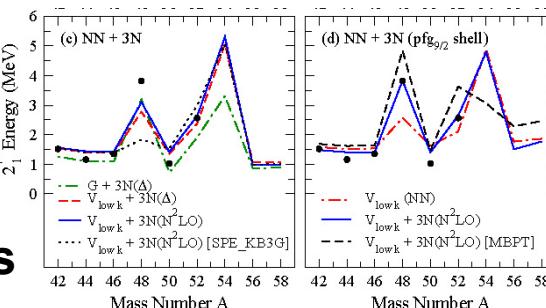
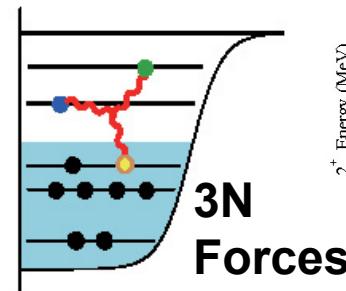
T.Otsuka PRL97 162501



Tensor interaction

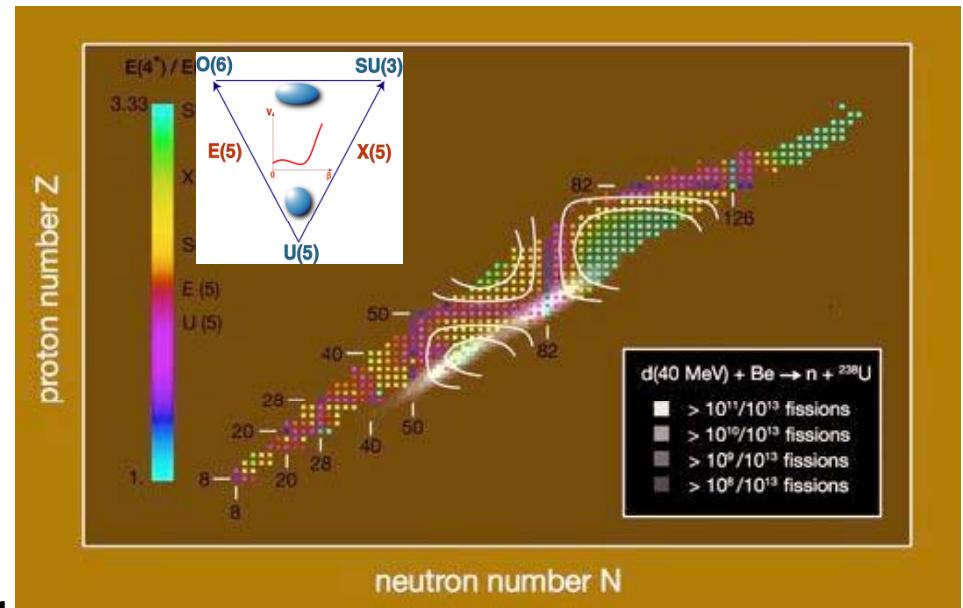
K. Sieja PRC81, 061303

T.Otsuka PRL105 032501, J.D Holt arXiv:1009.5984v1



Effects of diffuse nuclear matter

F.Hofmann et al, PRC 64(01)034314.



- Symmetries: New regions to study spherical, transitional and deformed nuclei, phase transitions. Dynamical and critical point symmetries

p-n Triaxial Deformation

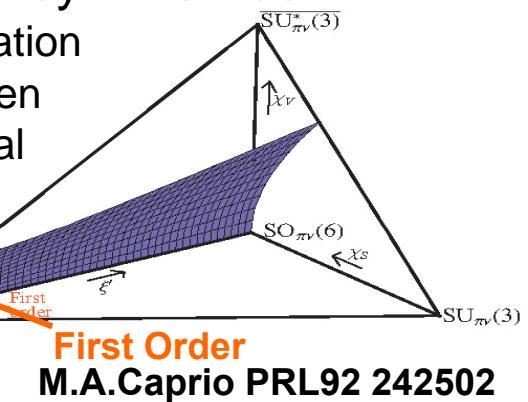
Critical Point between

Axial and p-n Triaxial
Deformation

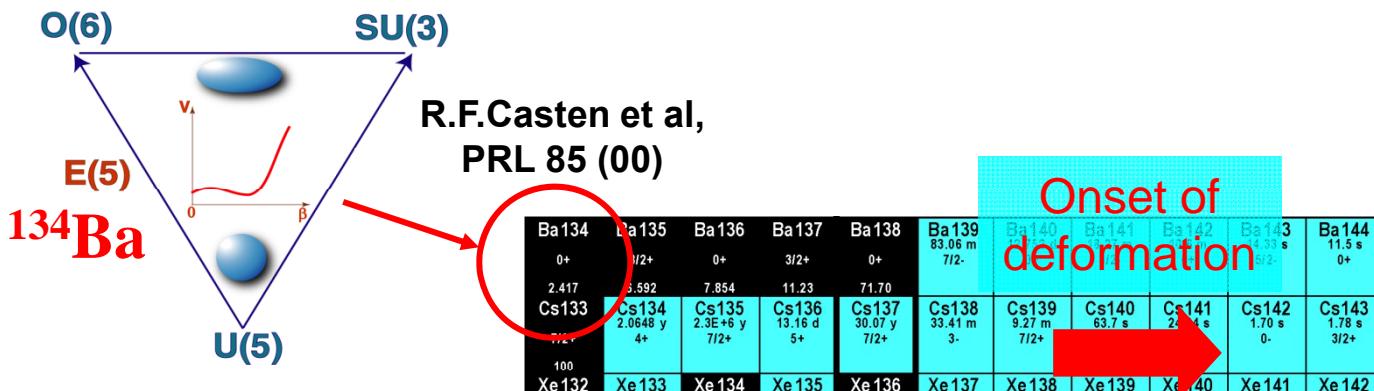
**Second
Order**

ond

First
Order

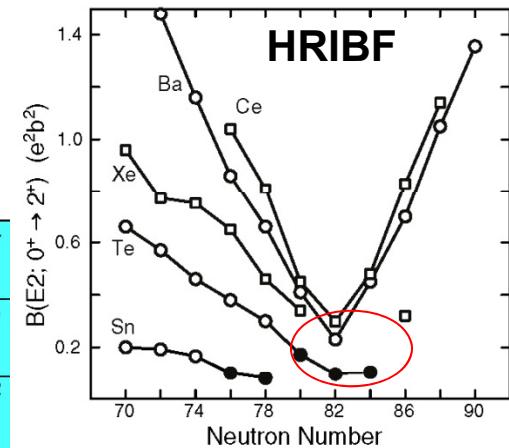
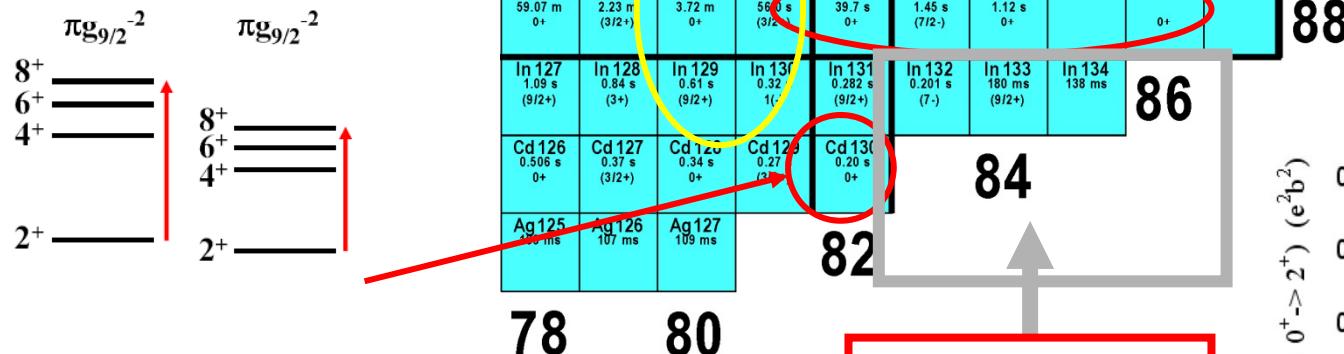


Structure in the ^{132}Sn region



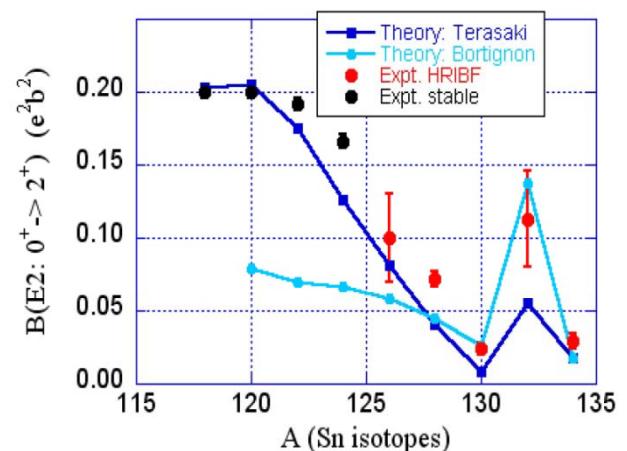
Shell Model nuclei
realistic CD-BONN
interaction

A.Sherillo et al, PRC70 (04)



D.C.Radford et al,
PRL 88 (2002)

J.Terasaki et al, PRC66 (02)
G.Colo et al., NPA722 (03)
A.Anvari, PLB623 (05)



Collective modes in the continuum / Hot nuclei

Shape phase transitions

Jacobi transition

(Oblate \rightarrow triaxial \rightarrow prolate)

Poincaré transition

(Prolate \rightarrow octupole)

Collective Rotation

- Order-to-Chaos Transition

Collective Vibrations

- Prompt dipole emission in CN reactions

- Giant Quadrupole Resonance

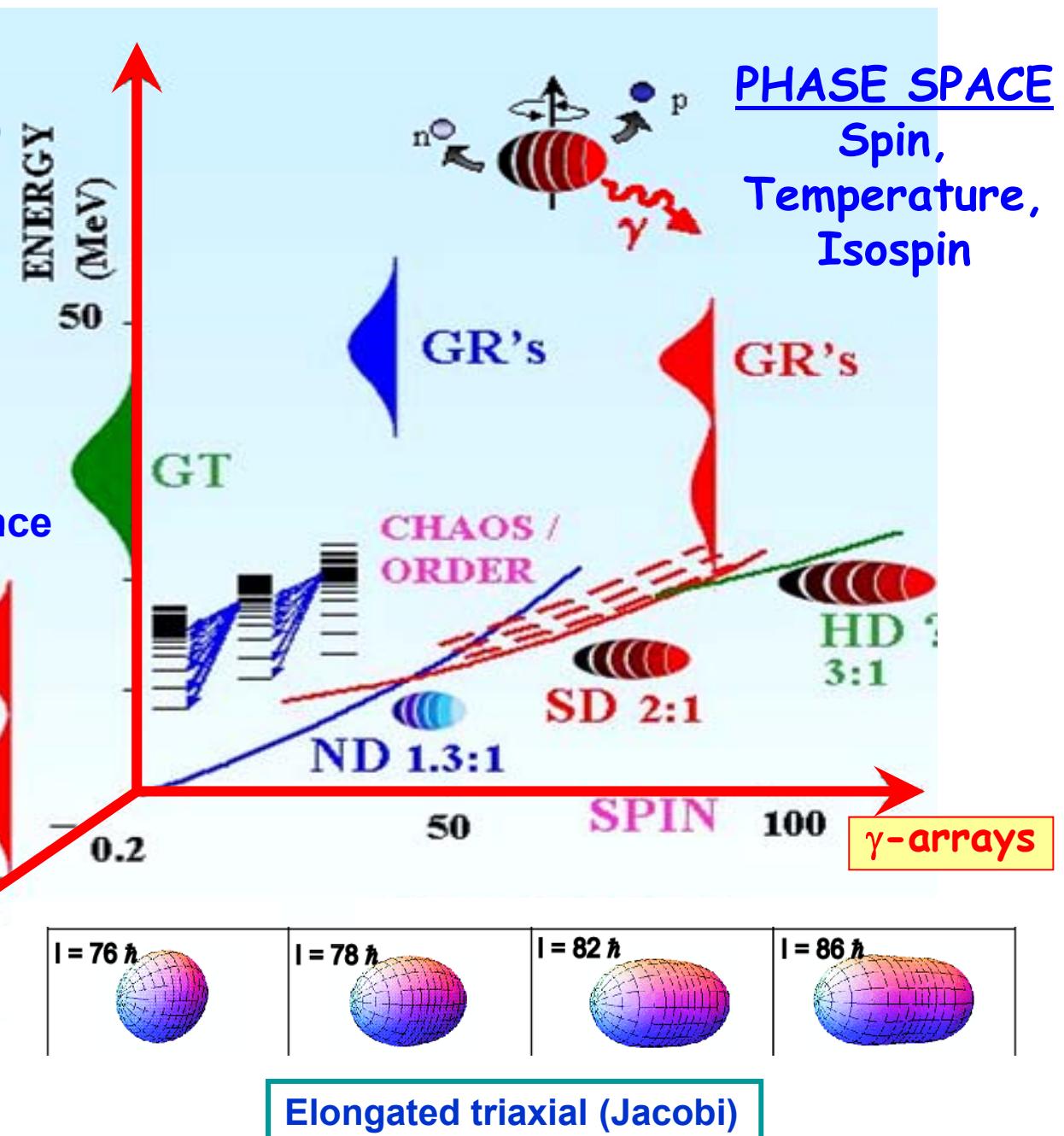
- Highly excited/Pygmy states in n-rich nuclei

SOFT GR's

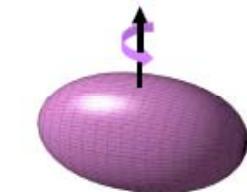
n-halo
n-skin
p-decay

ISOSPIN
(N-Z)/A

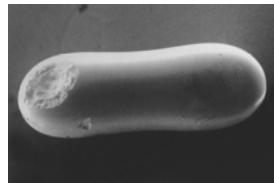
Exotic beams



Exotic nuclear shapes



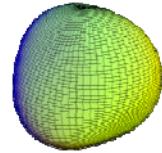
Superdeformation
Hyperdeformation



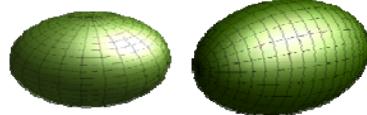
Jacobi shapes



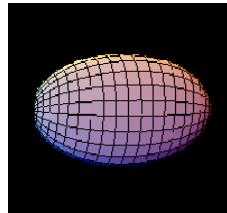
Triaxial shapes
3-dimensional rotation



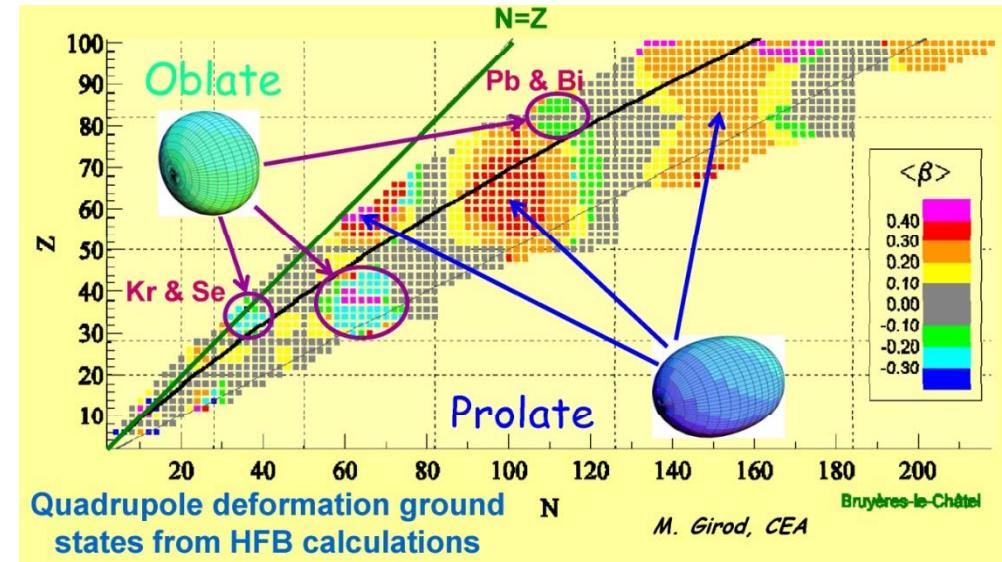
Higher-order shapes
(with high-rank symmetries):
tetrahedral, octahedral



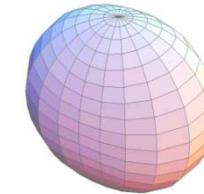
Shape coexistence



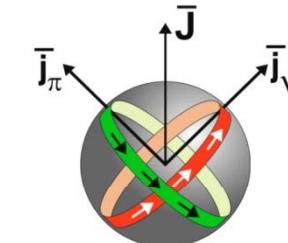
dynamic deformation
vibrations etc.



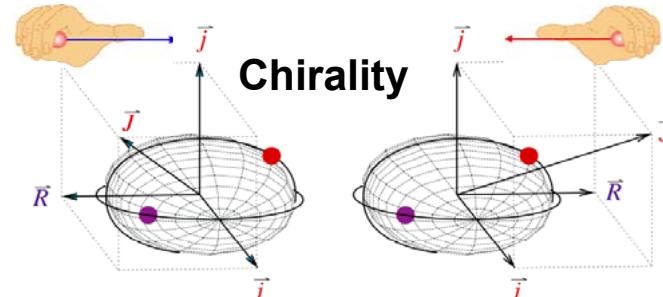
Phenomena associated:



Tidal Waves



Magnetic Rotation



Chirality

As well: Band termination Collapse of pairing,
wobbling modes, phase transitions, etc...

Instrumentation for High Resolution γ -Spectroscopy at SPES and SPIRAL2

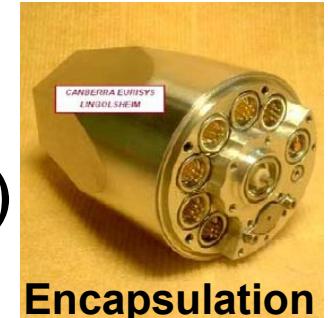
- Large Ge detector arrays for γ -Spectroscopy
- Complementarity with other instruments for γ -rays, particle or reaction product detection



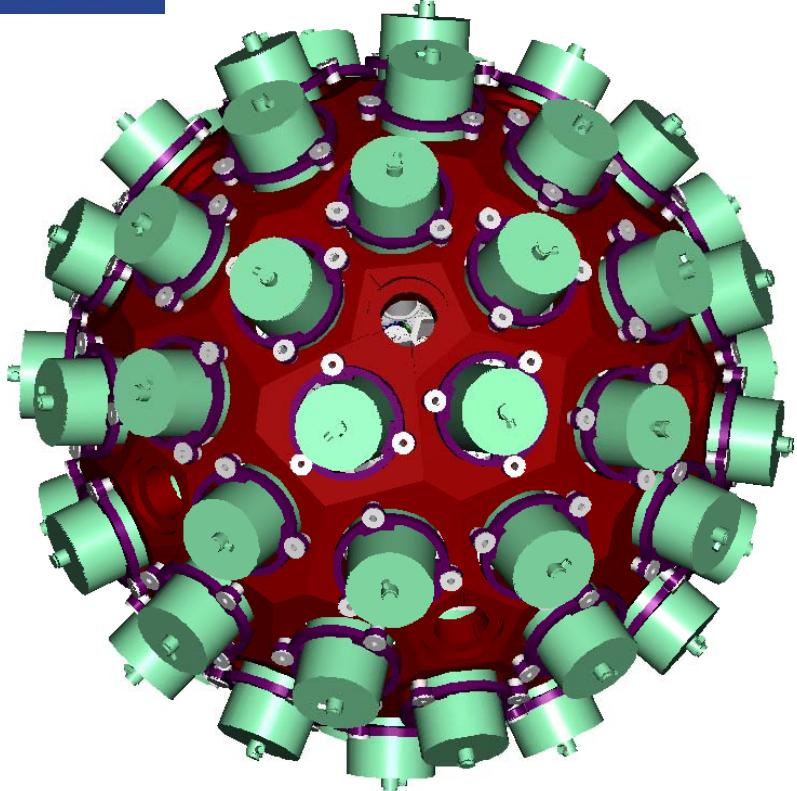


AGATA

(Advanced GAmma Tracking Array)



Encapsulation



180 hexagonal crystals	3 shapes all equal
60 triple-clusters	23.5 cm
Inner radius (Ge)	362 kg
Amount of germanium	82 %
Solid angle coverage	6480 segments
36-fold segmentation	~50 kHz
Singles rate	
Efficiency:	43% ($M_\gamma=1$) 28% ($M_\gamma=30$)
Peak/Total:	58% ($M_\gamma=1$) 49% ($M_\gamma=30$)

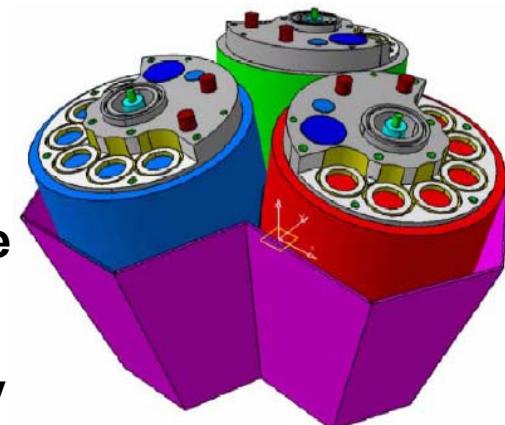
6660 high-resolution digital electronics channels

High throughput DAQ

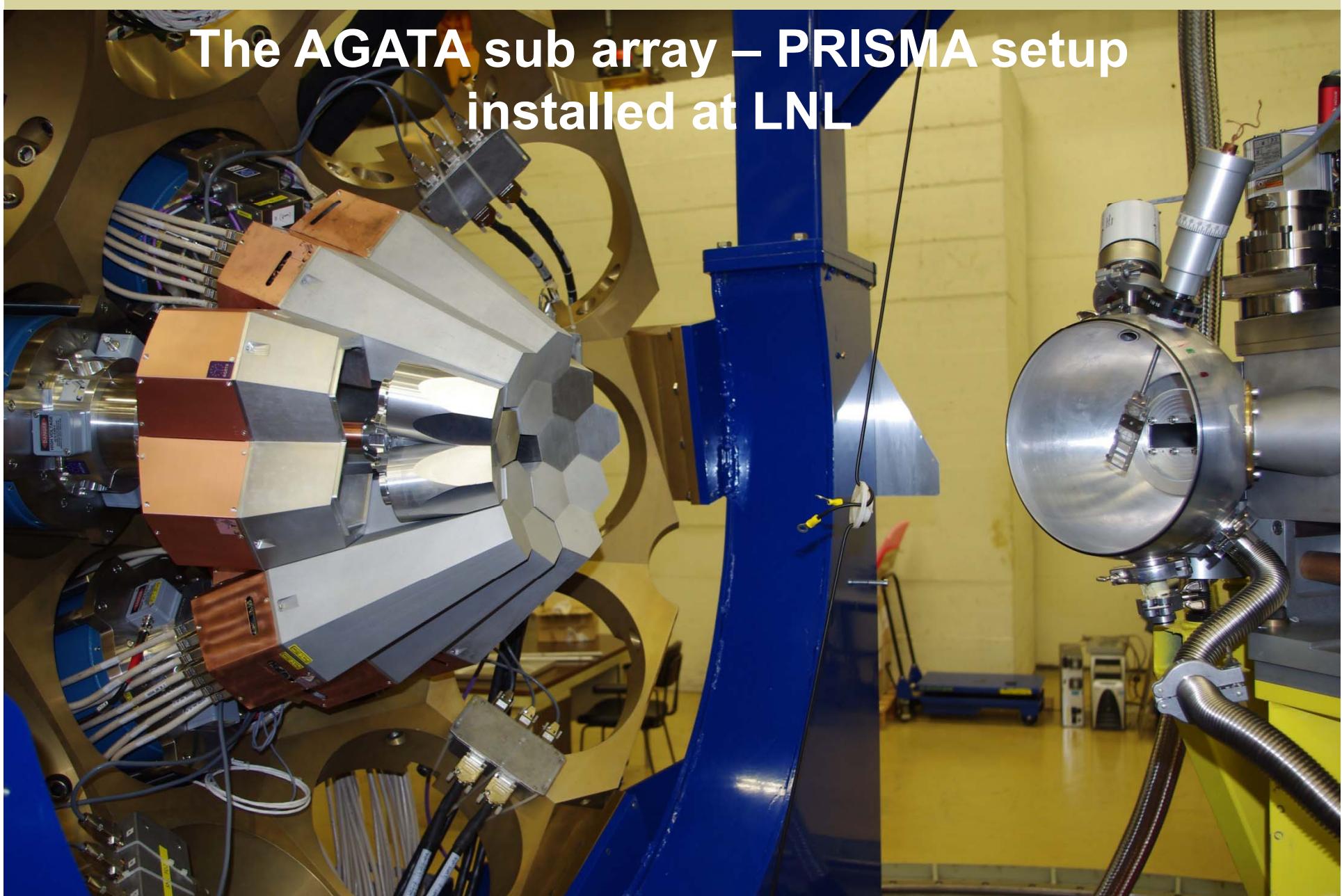
Pulse Shape Analysis → position sensitive operation mode

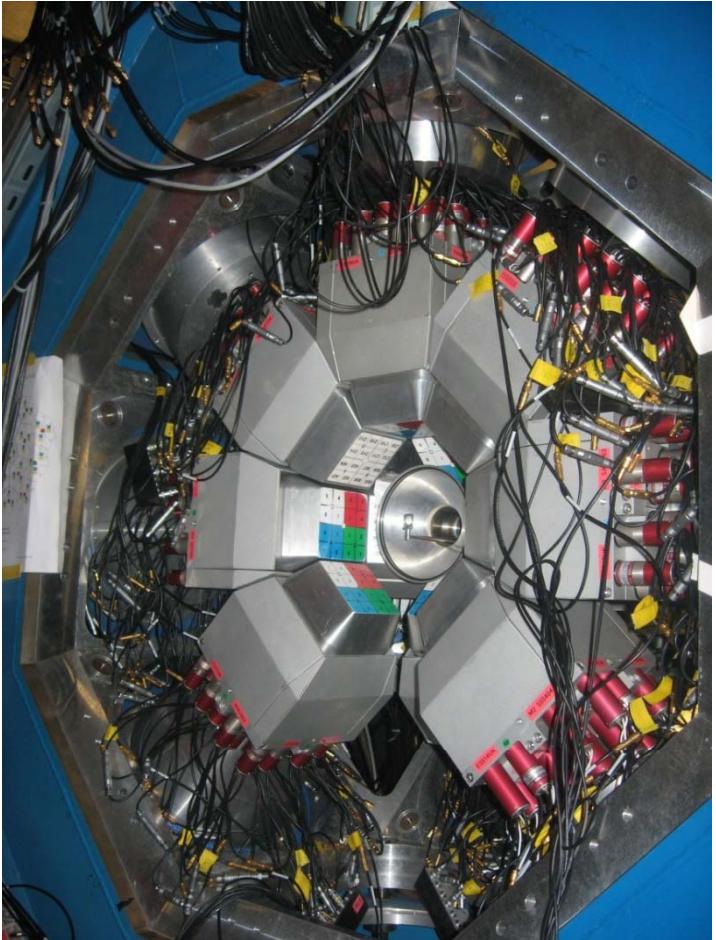
γ -ray tracking algorithms to achieve maximum efficiency

Coupling to complementary detectors for added selectivity



The AGATA sub array – PRISMA setup installed at LNL



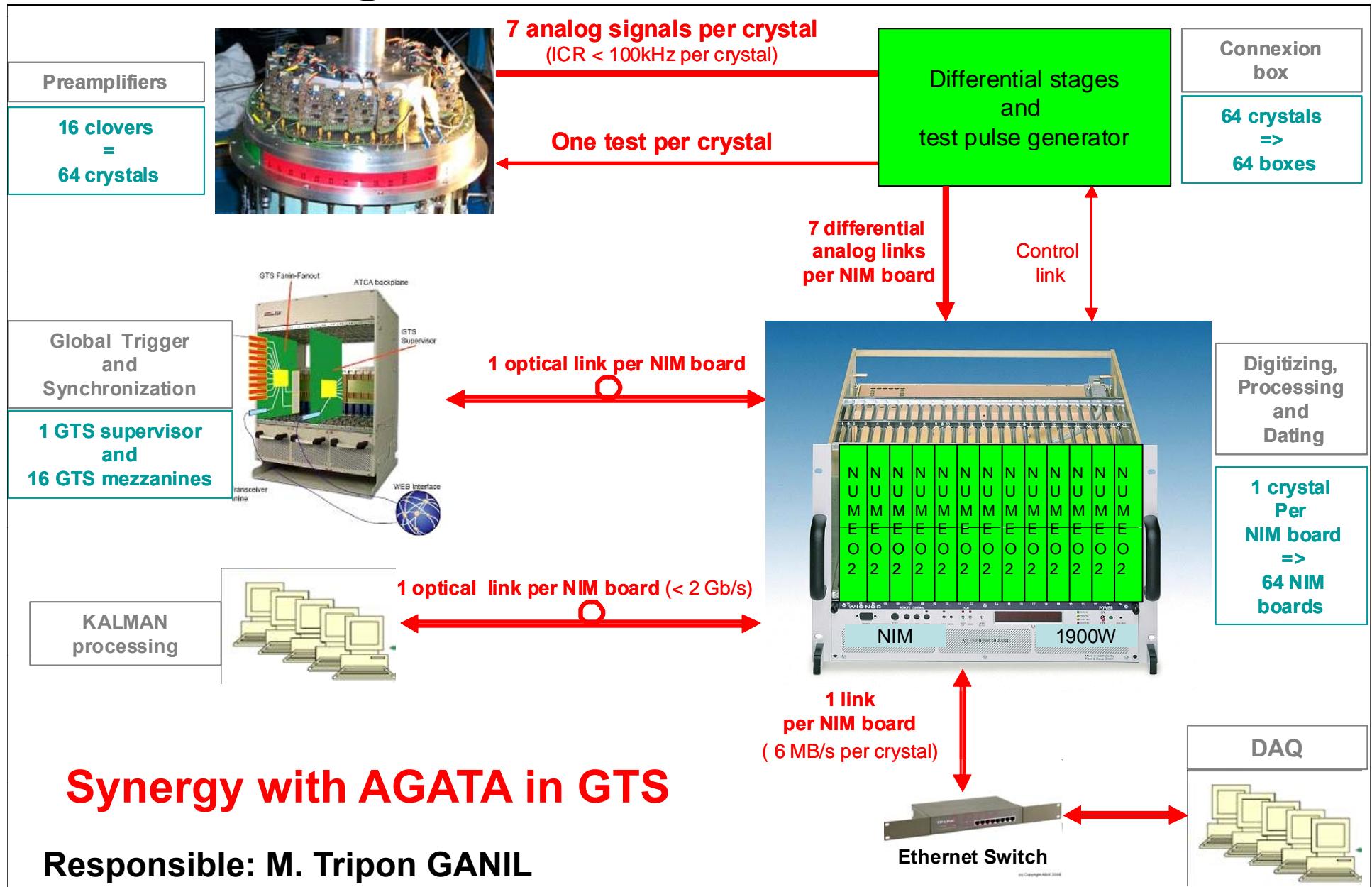


Spokesperson: G. de France
GANIL

Upgrade of the compact array EXOGAM (FP7 SPIRAL2 preparatory phase).

- Upgrade to digital electronics. New FEE and data processing → synergy with AGATA.
- Digital electronics and high counting rate capability by digital pulse processing.
 - Capability to stand high background counting rates from RIBs and high intensity stable beams
- Very efficient with reactions providing limited angular momentum
- Foreseen:
 - Use of KALMAN processing for higher counting rates ~100kHz/crystal.
 - Under study the use of PSA to improve performance

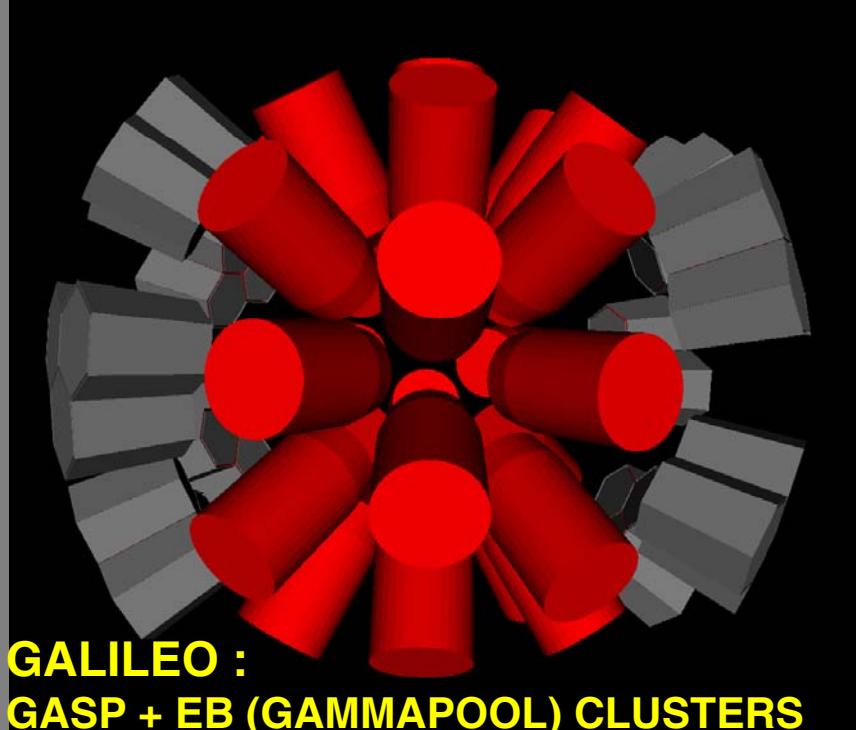
EXOGAM2 general architecture



The GASP and GALILEO arrays



Spokesperson: C.Ur INFN-Padova

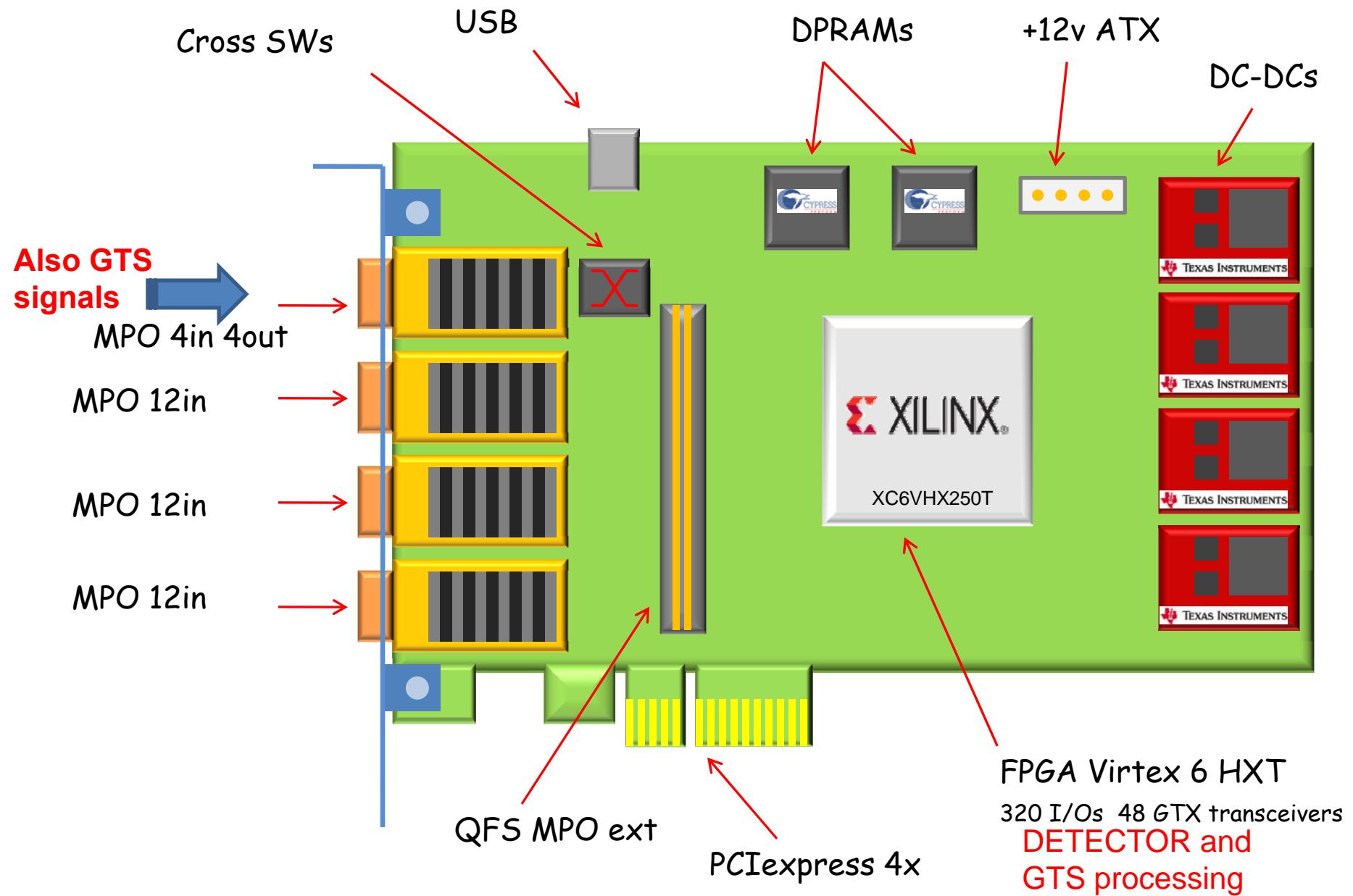


GALILEO Mixed configuration with
40 GASP dets. and 10 x 3-Clusters

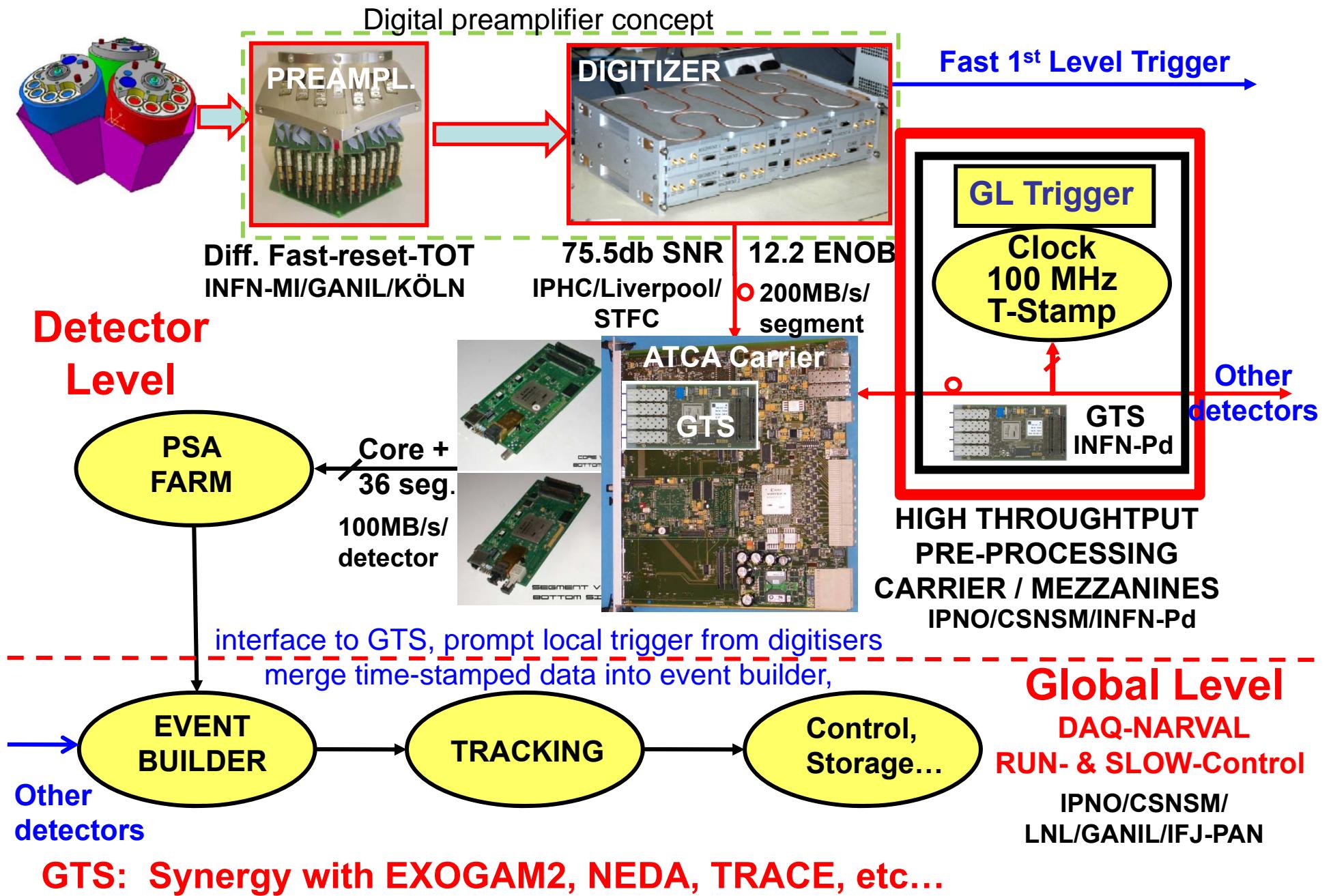
Symmetric configuration of the array

GASP anti-Compton shields available

GALILEO FRONT-END PROCESSING

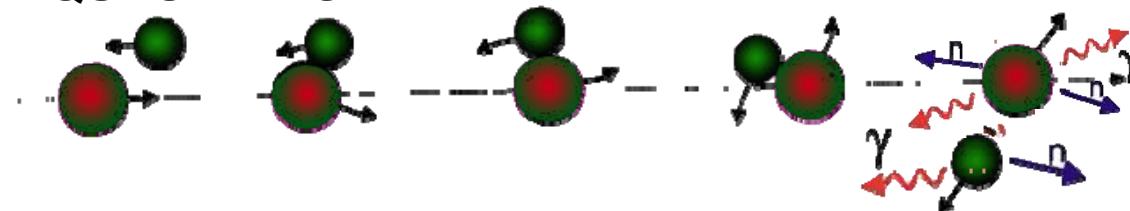


AGATA Structure of Electronics and DAQ

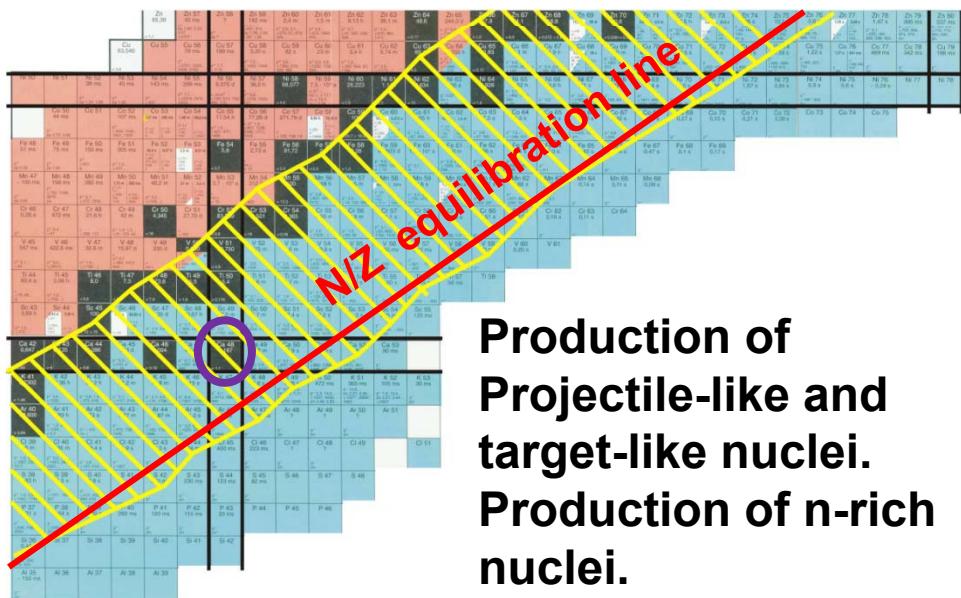
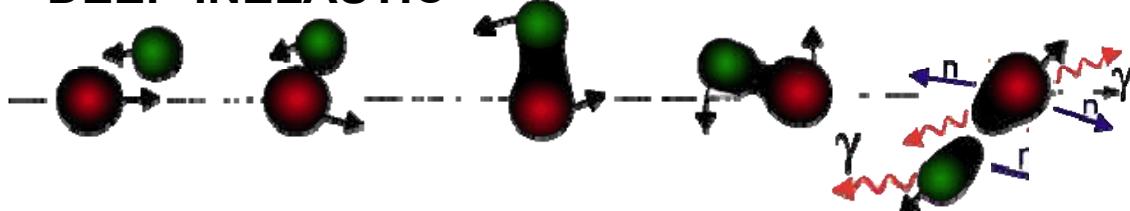


GRAZING and DIC REACTIONS

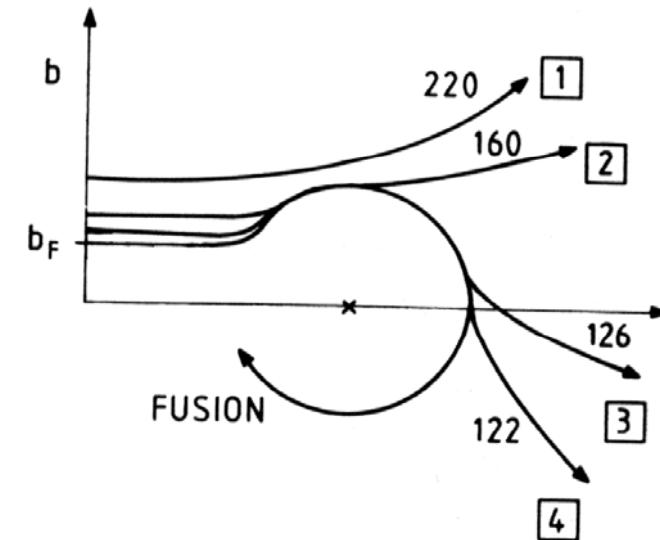
QUASI-ELASTIC



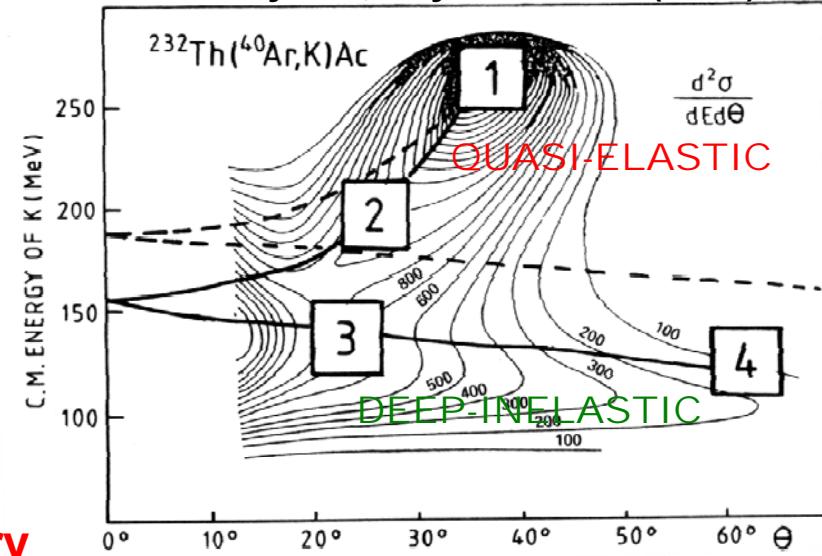
DEEP-INELASTIC

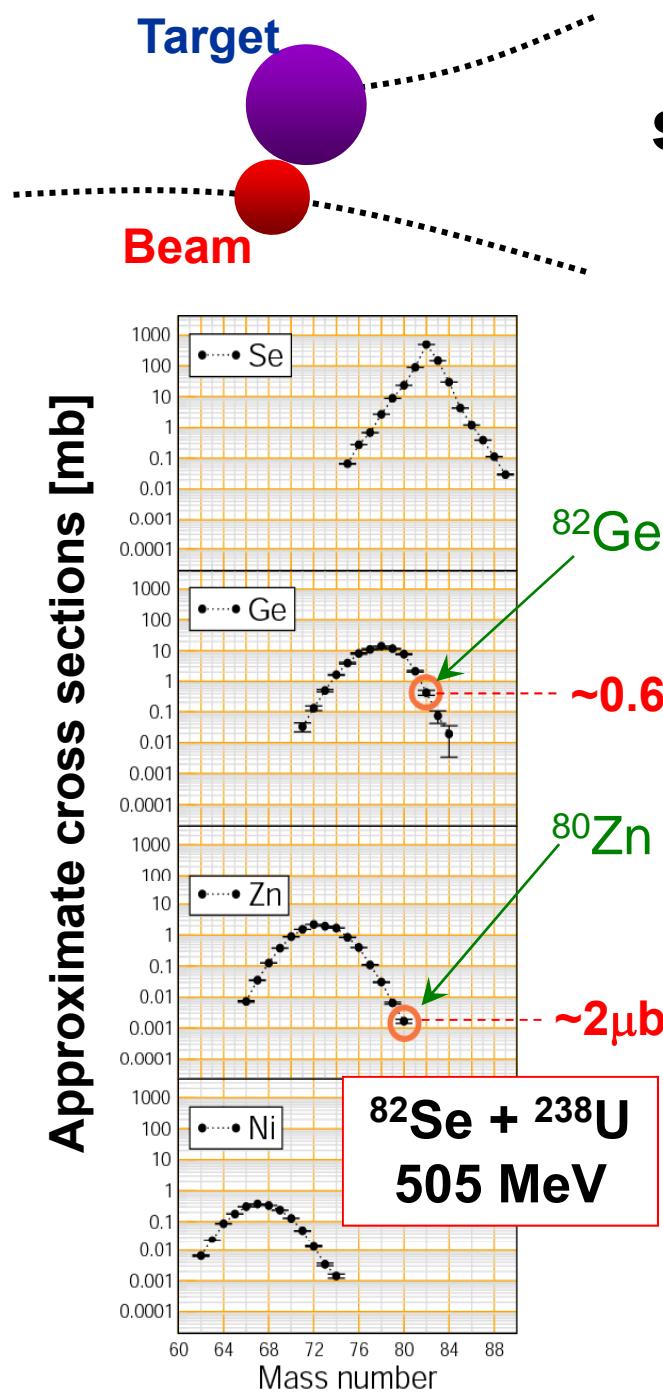


Identification of products with complementary detectors or by γ -spectroscopy of the partners is required



J. Wilczynski, Phys. Lett. 47B(1973) 484

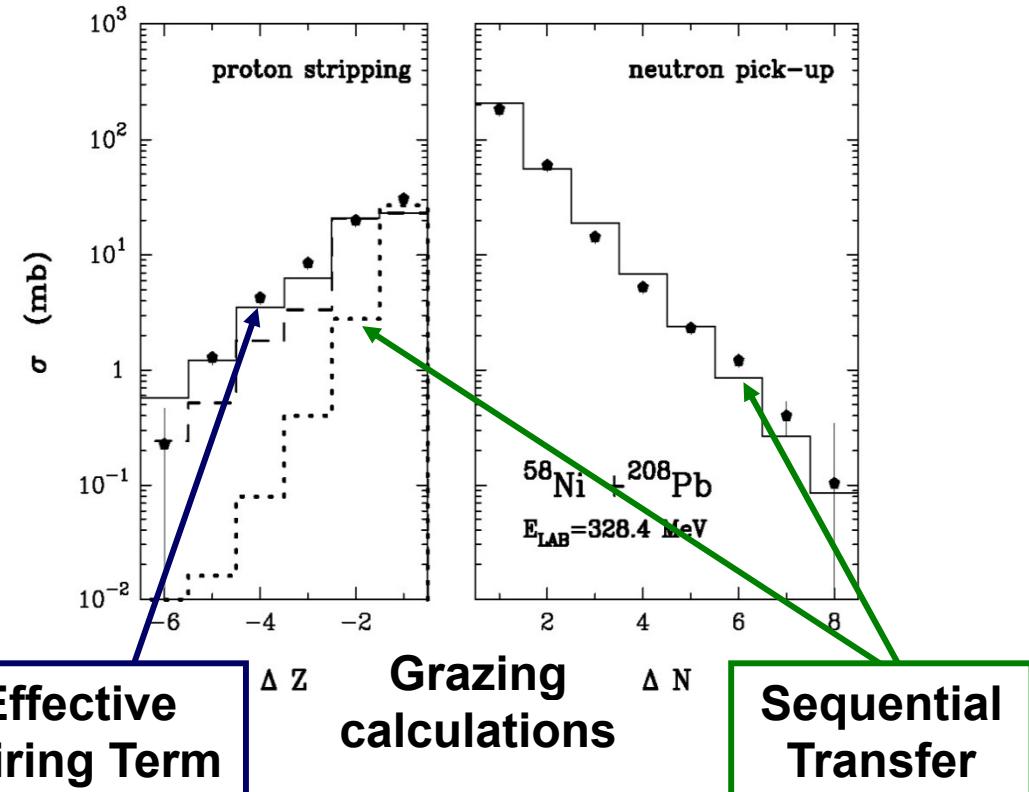


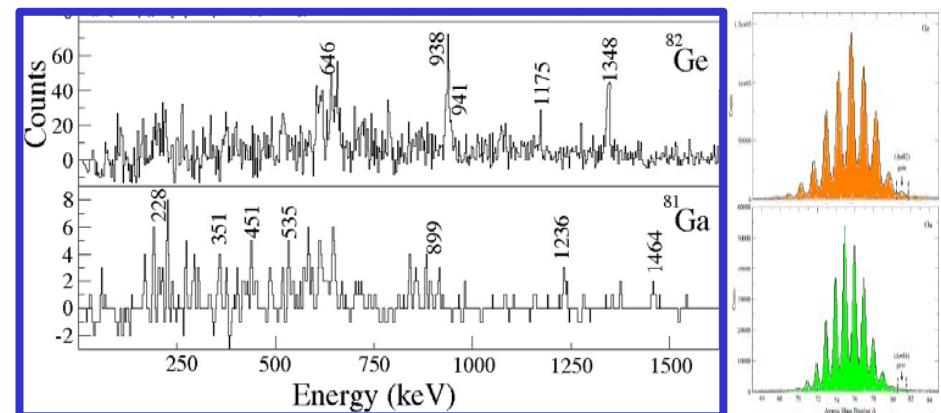
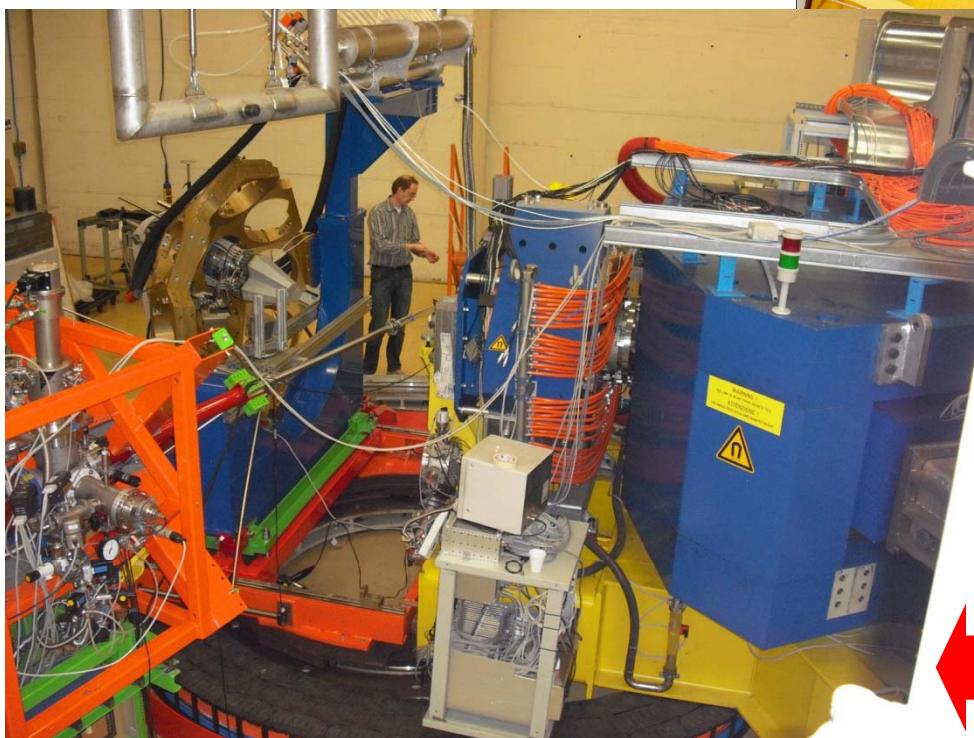
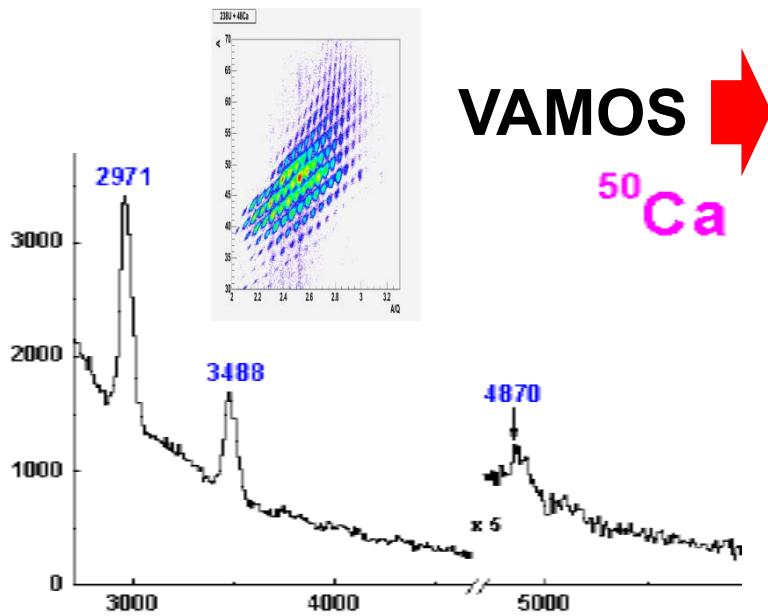


Grazing reactions transferring several nucleons, a tool to study neutron-rich nuclei

Deep-inelastic reactions used since thick target pioneering work of R.Broda et al. (PLB 251 (90) 245)

Use of Multinucleon-transfer at the grazing angle triggered by the LNL reaction mechanism group.



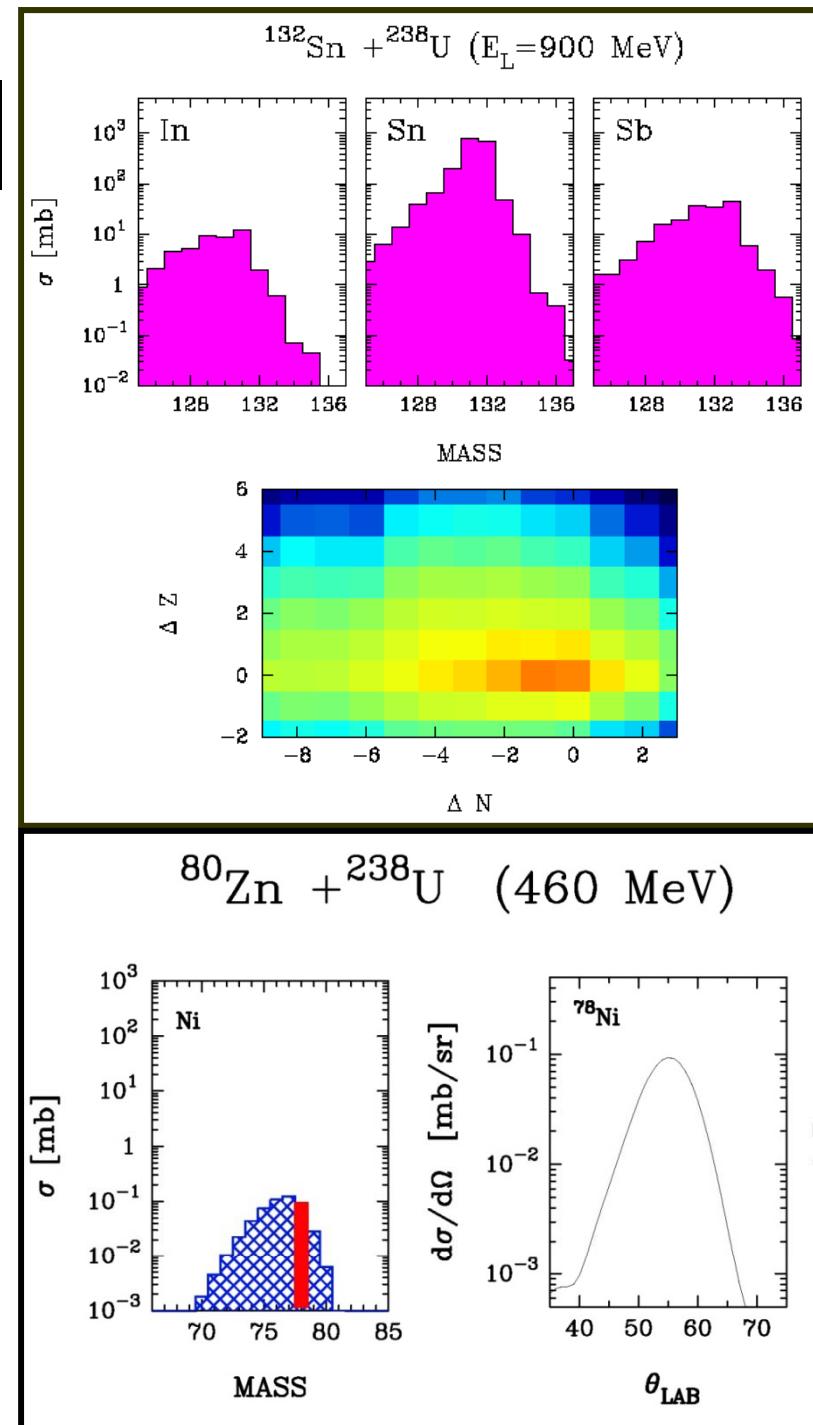


Intensities from n-induced fission



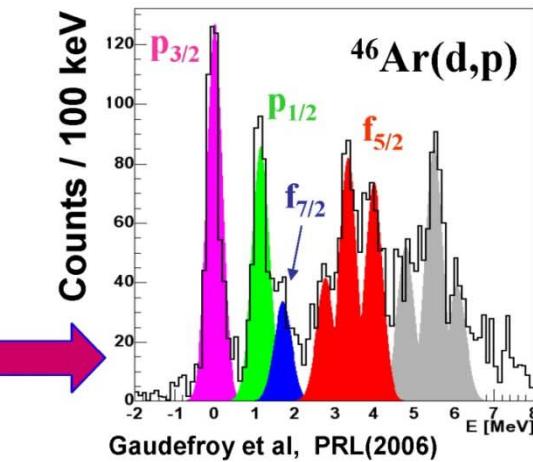
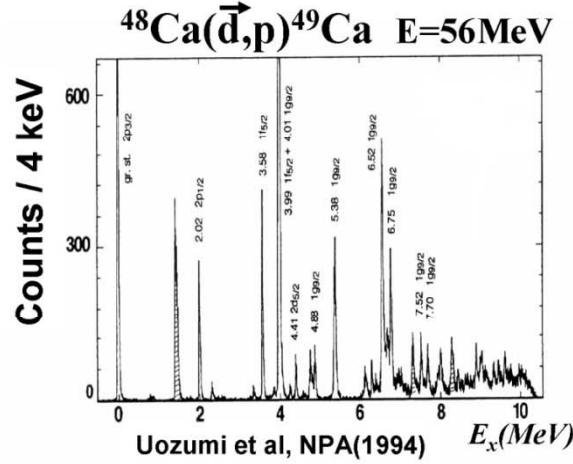
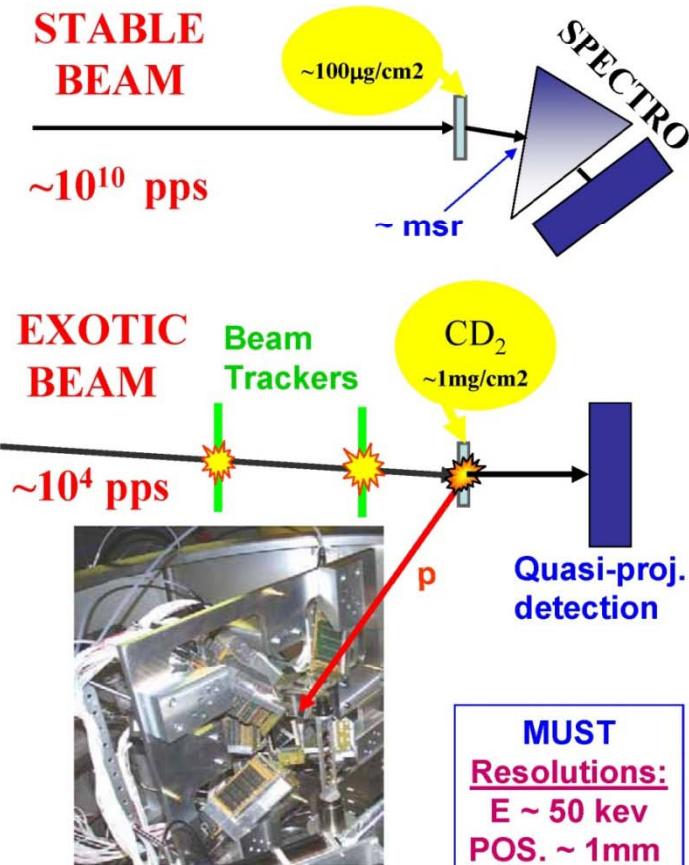
Isotope	Half life	E_{nom} /A·MeV	$I(E_{\text{nom}})$ /pps	E_{min} /A·MeV	$I(E_{\text{min}})$ /pps	E_{max} /A·MeV	$I(E_{\text{max}})$ /pps
79Zn	995 ms	6.2	2.1E+04	1.5	2.1E+04	12.3	2.0E+03
80Zn	545 ms	6.0	6.2E+03	1.5	6.4E+03	12.0	6.1E+02
86Kr	stbl	7.1	5.8E+08	1.8	5.7E+08	14.4	5.8E+07
87Kr	76.3 m	6.9	5.9E+08	1.7	5.9E+08	14.1	5.9E+07
88Kr	2.84 h	6.8	7.0E+08	1.7	7.0E+08	13.8	7.0E+07
89Kr	3.15 m	6.6	7.5E+08	1.6	7.5E+08	13.5	7.5E+07
90Kr	32.32 s	6.5	6.4E+08	1.6	6.4E+08	13.2	6.4E+07
91Kr	8.57 s	6.3	5.2E+08	1.6	5.2E+08	12.9	5.2E+07
92Kr	1.84 s	6.2	2.6E+08	1.5	2.7E+08	12.6	2.6E+07
93Kr	1.286 s	6.1	8.8E+07	1.5	8.9E+07	12.3	8.6E+06
94Kr	210 ms	5.9	1.2E+07	1.5	1.3E+07	12.1	1.1E+06
95Kr	114 ms	5.8	1.1E+06	1.4	1.3E+06	11.8	1.0E+05
96Kr	80 ms	5.7	1.1E+05	1.4	1.2E+05	11.6	9.2E+03
131Sn	56 s	5.1	8.2E+06	1.3	8.2E+06	9.7	8.2E+05
131Snm	58.4 s	5.1	3.0E+07	1.3	3.0E+07	9.7	3.0E+06
132Sn	39.7 s	5.0	1.8E+07	1.2	1.8E+07	9.6	1.8E+06
133Sn	1.45 s	4.9	6.3E+05	1.2	6.4E+05	9.4	6.2E+04
134Sn	1.12 s	4.8	5.9E+04	1.2	6.0E+04	9.3	5.8E+03
136Te	17.63 s	5.2	1.6E+07	1.3	1.6E+07	9.8	1.6E+06
135Xe	9.14 h	5.3	1.6E+09	1.3	1.6E+09	9.9	1.6E+08
35Xem	15.29 m	5.3	2.7E+08	1.3	2.7E+08	9.9	2.7E+07
136Xe	stbl	5.2	1.9E+09	1.3	1.9E+09	9.8	2.0E+08
137Xe	3.818 m	5.1	1.4E+09	1.3	1.4E+09	9.6	1.4E+08
138Xe	14.08 m	5.1	1.2E+09	1.3	1.2E+09	9.5	1.2E+08
139Xe	39.68 s	5.0	8.2E+08	1.2	8.2E+08	9.3	8.2E+07
140Xe	13.6 s	4.9	4.9E+08	1.2	4.9E+08	9.2	4.9E+07
141Xe	1.73 s	4.9	1.0E+08	1.2	1.0E+08	9.1	1.0E+07
142Xe	1.22 s	4.8	2.9E+07	1.2	2.9E+07	9.0	2.8E+06

Attention: early productions more compatible with direct reactions and Coulomb excitation



Direct Reactions Si-arrays coupled with Ge-arrays for the new RIBs facilities

Experimental Methods



Current instruments: **EXOGAM + TIARA + MUST + VAMOS**

D.Beaumel, GASPARD Collaboration

Scientific Case for GASPARD

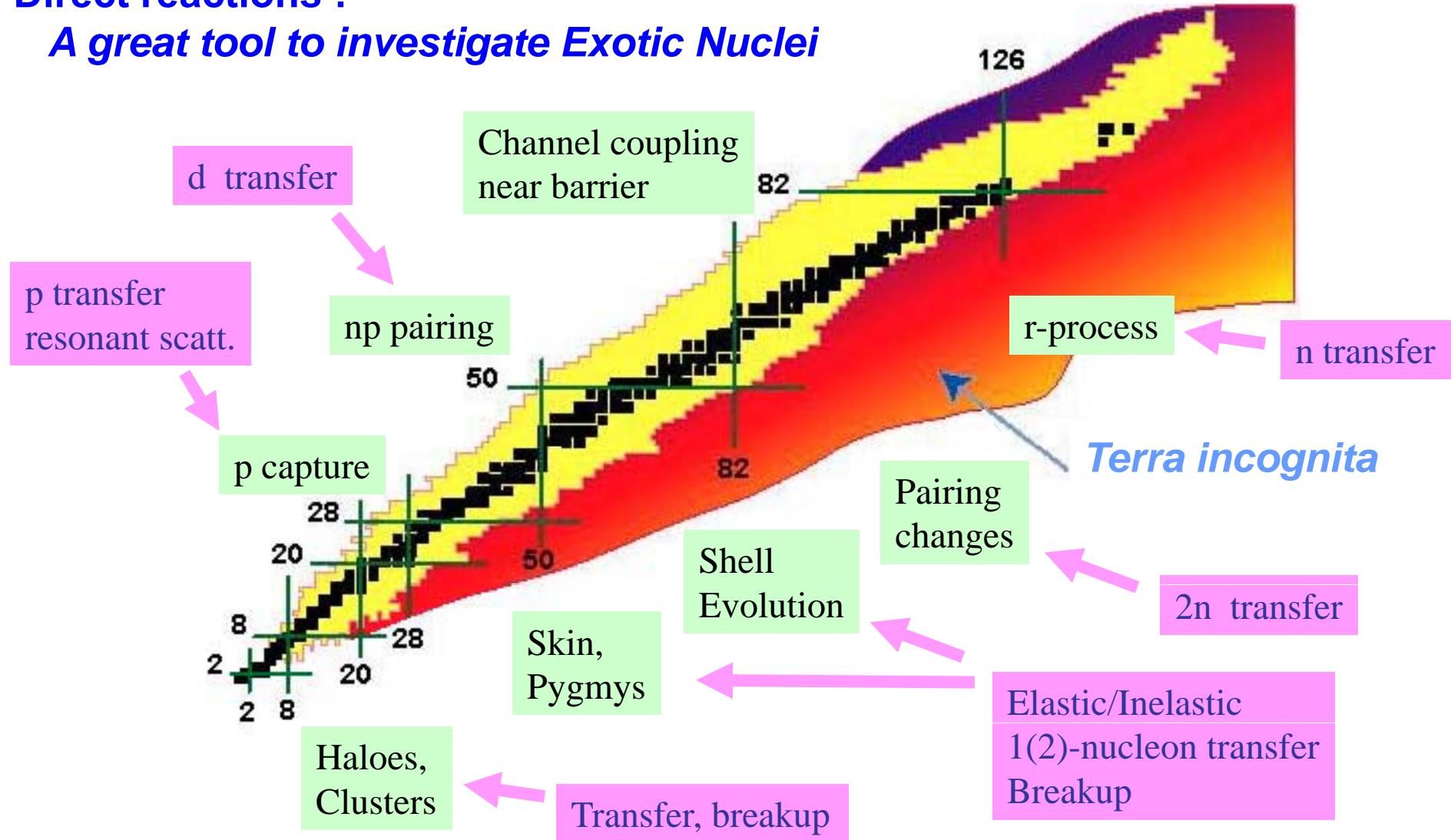
Lots of Physics opportunities with



beams !

Direct reactions :

A great tool to investigate Exotic Nuclei



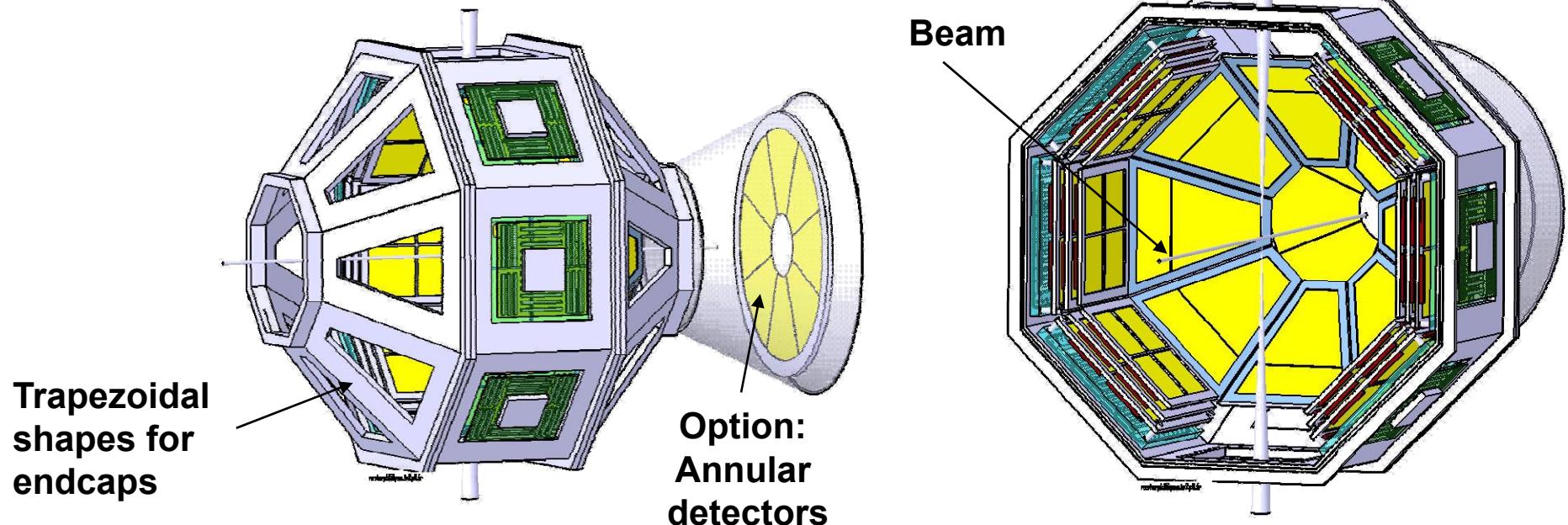


GASPARD *Preliminary design*

GAmma SPectroscopy and PArticle Detection

“GASPHYDE” design - fit inside AGATA
Towards a common project with HYDE

Basis: DSSD's, 4" technology



- Improved PID for light particle
 - ✓ PSA with DSSD's
- Integrate special targets
 - ✓ Pure&windowless H/D (the CHYMENE project)
 - ✓ He cooled gas

ELECTRONICS:
~ 15000 channels (Digital)
• Integration and effects on γ -ray now under study (simulations)
Preamps to be under vacuum



R&D on a light charged particle telescope-detector array for direct reactions

Based on Si-PAD ΔE -E telescopes

To be used coupled with AGATA

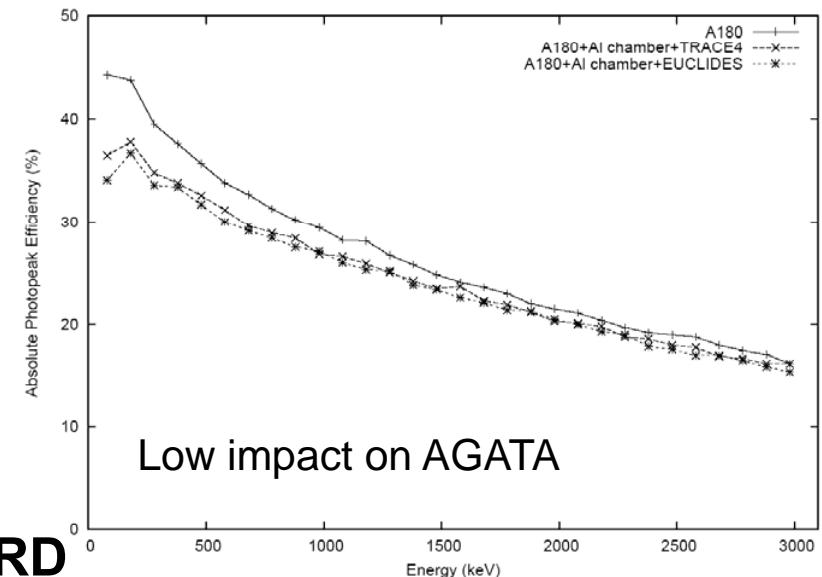
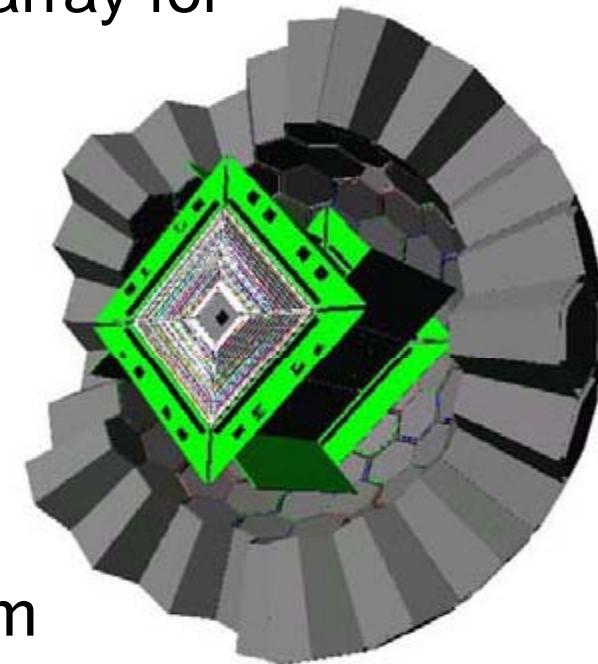
Solid angle coverage 80-90%

High counting rate: 20 kHz per PAD

ΔE : Si-pad det. $\sim 150 \mu\text{m}$, 4mm x 4 mm

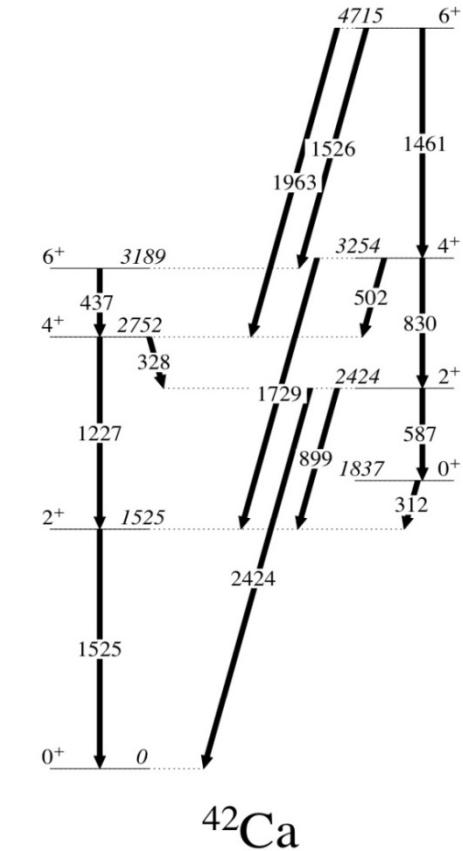
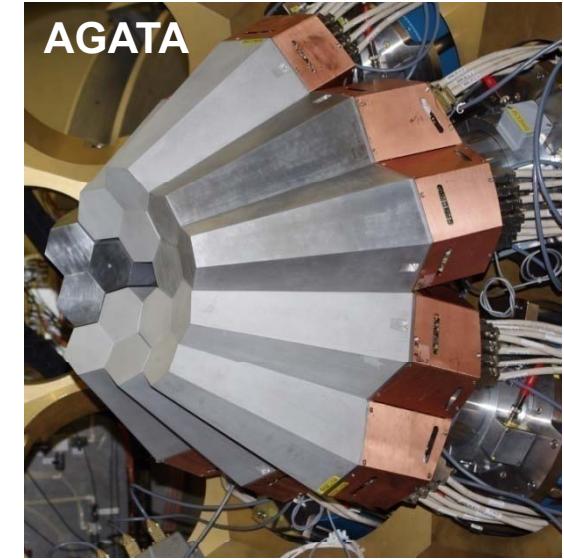
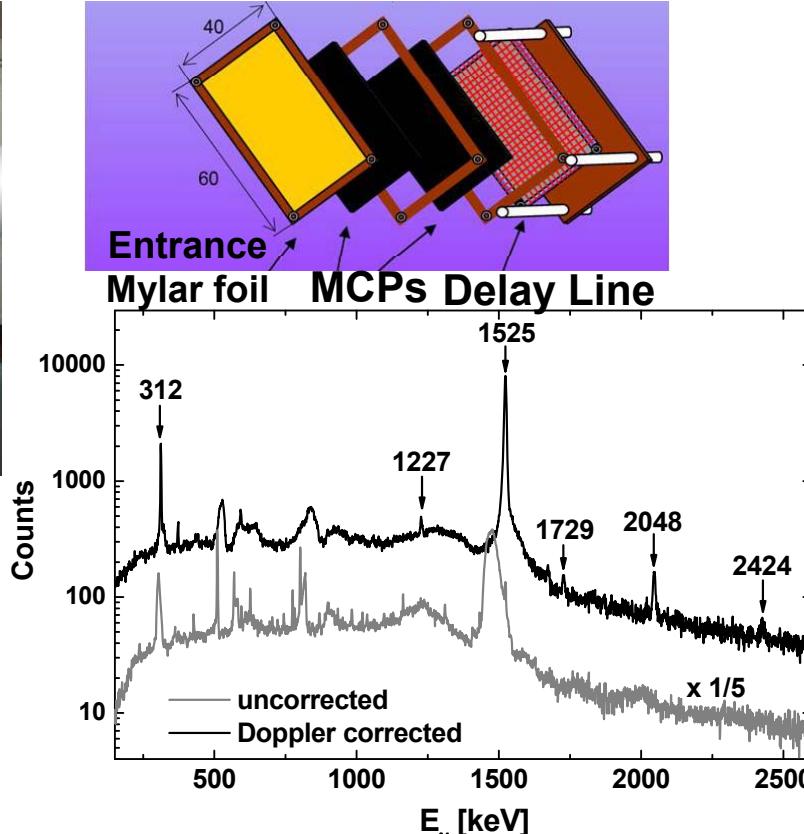
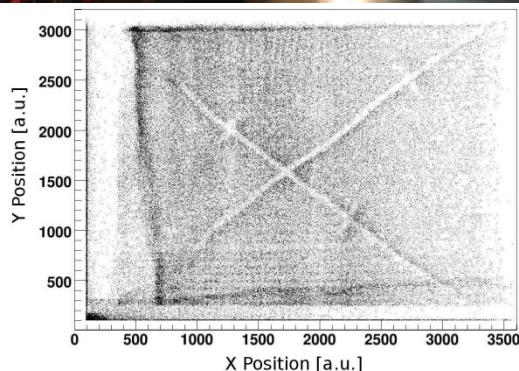
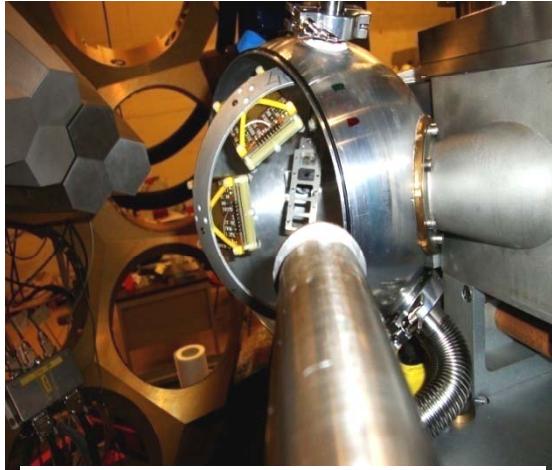
E: Si-pad det. $\sim 1-1.5 \text{ mm}$, 4mm x 4 mm

PSA and mirror signals in neighboring PADs (position)



The DANTE heavy ion detector array: First Coulex AGATA Experiment

DANTE: J.J.Valiente Dobon INFN-LNL

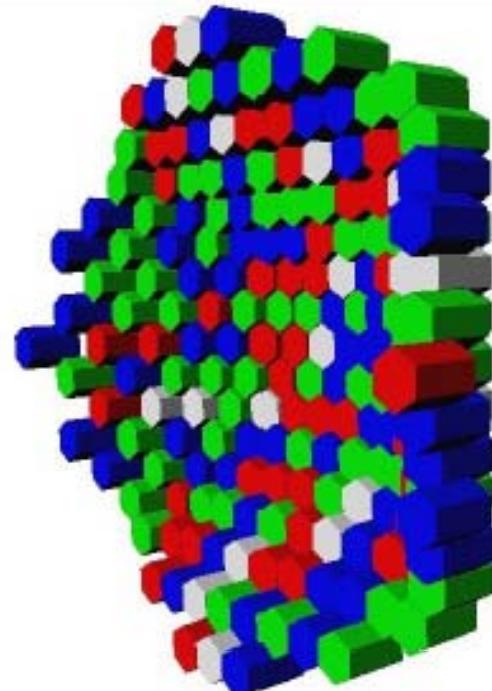


Preliminary γ spectra (uncorrected and Doppler corrected using DANTE position information) from AGATA Demonstrator. The indicated γ -ray energies correspond to the transitions from the lowest excited states in ^{42}Ca

Neutron Detector Array: NEDA

There are two possible main geometries, either spherical or planar.

- Optimize for efficiency (within the solid angle coverage)
- Minimizing the cross talk (interaction in more detectors) with Planar geometry:
 - Flexibility – different arrangements of the detectors, e.g. zig-zag
 - Different focal positions (500cm, 1000cm, 2000cm)



Step-spherical

J.J.Valiente-Dobon INFN-LNL



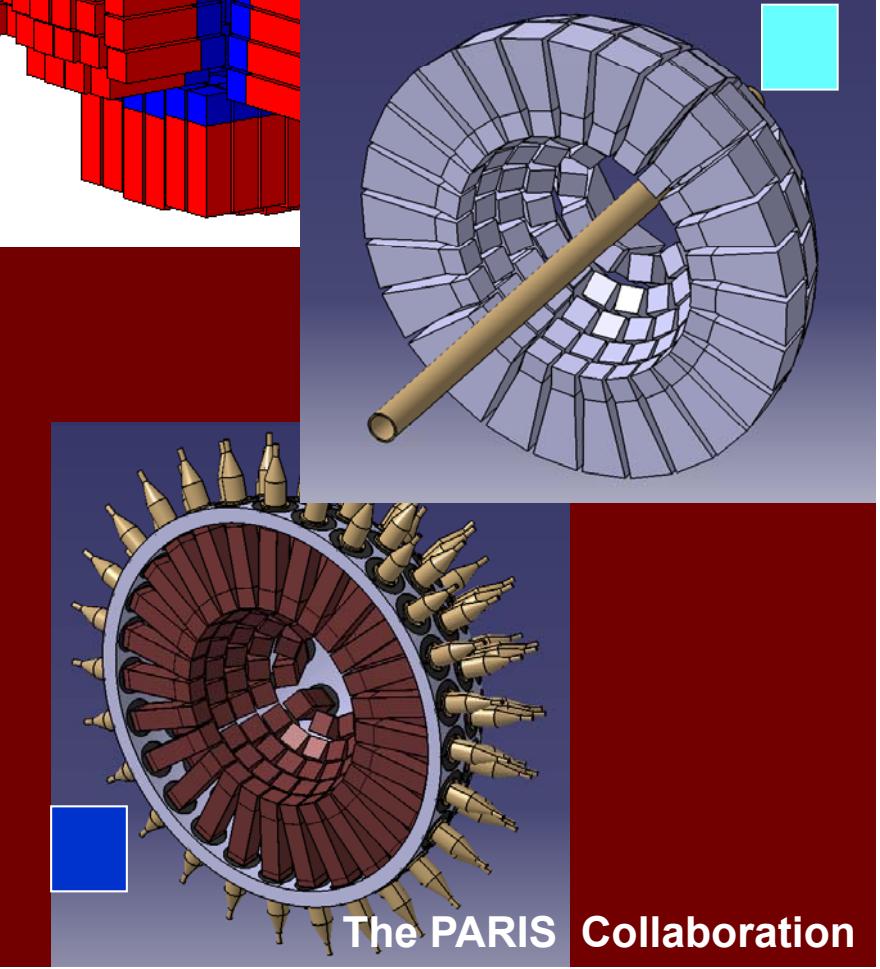
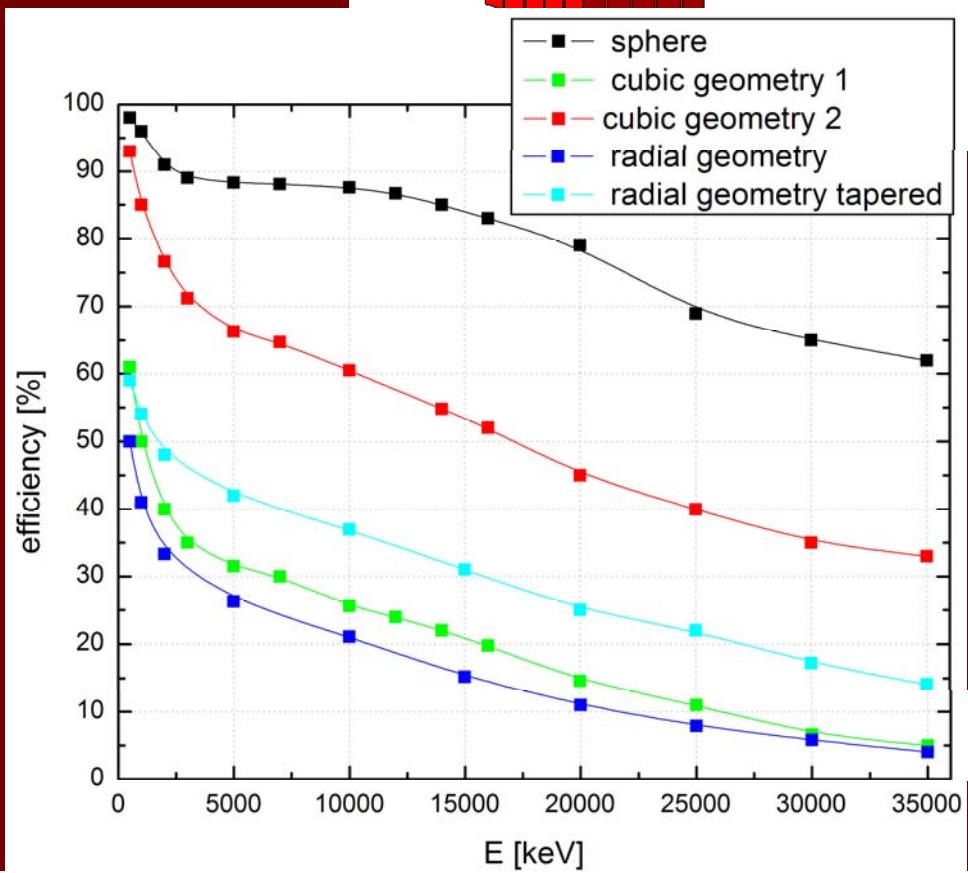
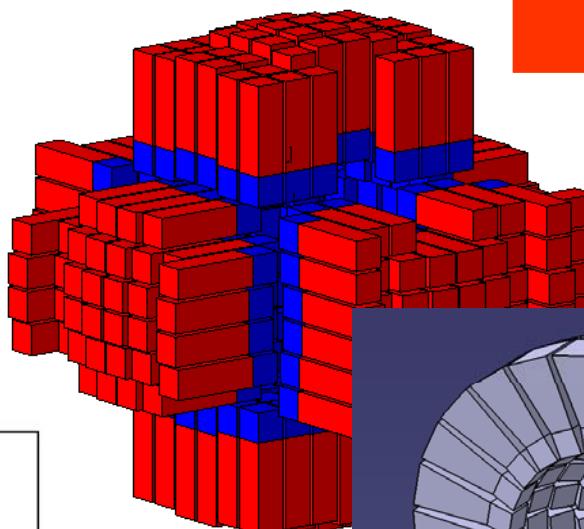
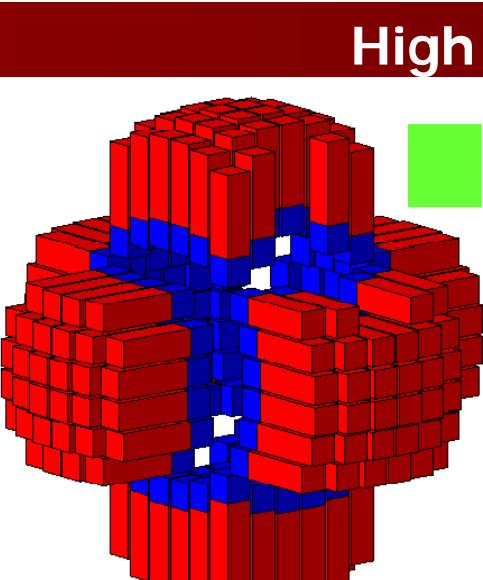
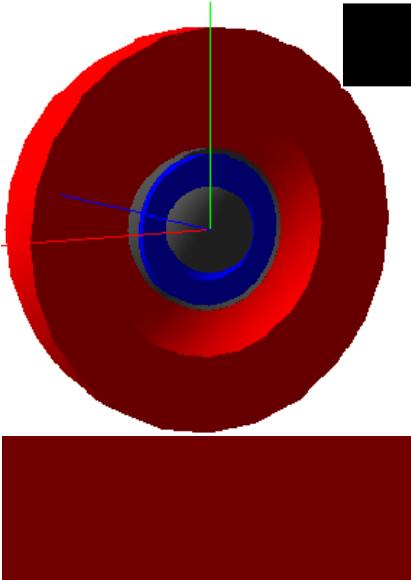
Spherical

**For $N \sim Z$ studies
needed as well a
 4π light charged
particle detector:
EUCLIDES (LNL)
DIAMANT (GANIL)**



High Energy γ -ray detector array PARIS

A.Maj IFJ-PAN Cracow



The PARIS Collaboration

Summary:

- High Resolution γ -Spectroscopy is a essential technique to study the nuclear structure in the new generation RIB facilities.
- Several topics in n-rich as well as p-rich and on collective excitations can provide answers to fundamental questions.
- A large effort is being done to build and upgrade the most challenging instruments to cope with the demanding experimental conditions in RIB's facilities.
- To create synergies in particular in the LEA framework is an important issue for the success in our field.

