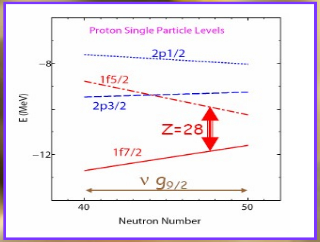
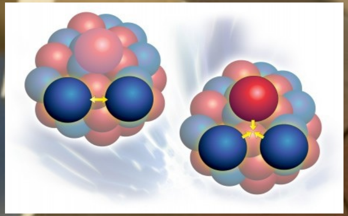
The AGATA Campaign at GANIL

Silvia M. Lenzi
University of Padova and INFN

Inpc 2016
International Nuclear Physics Conference
Adelaide Convention Centre, Australia
11-16 September 2016

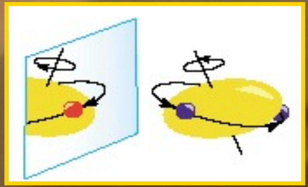
Shell evolution far from stability



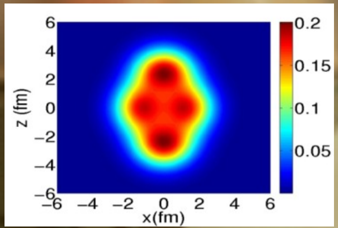


Three-body forces

Isospin symmetry breaking

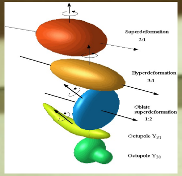


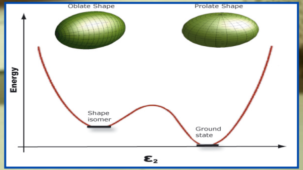
clusterization



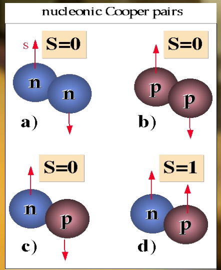
High-resolution gamma-ray spectroscopy is an optimum tool to study nuclear structure properties and investigate how they emerge from fundamental interactions.

Nuclear shapes and coexistence





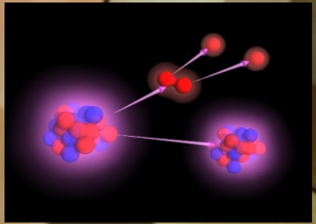
p-n pairing



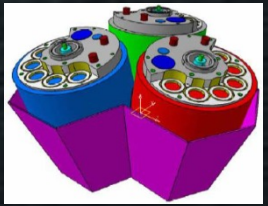
Super heavy elements

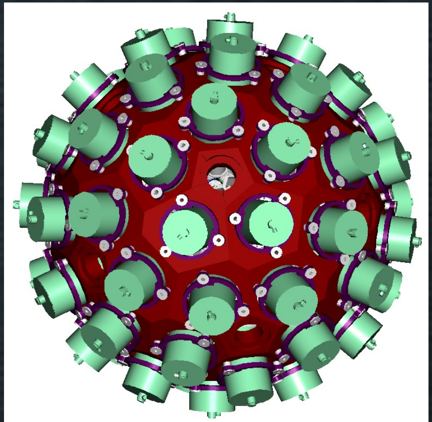
Nuclear Astrophysics

Coupling to the continuum

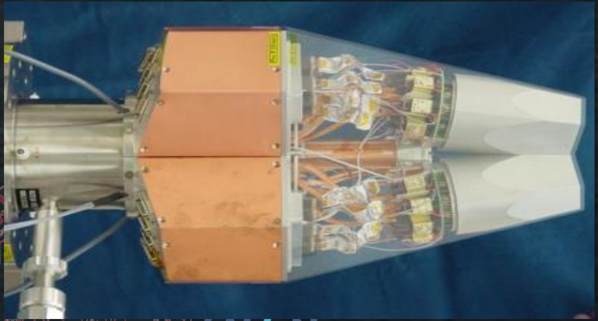


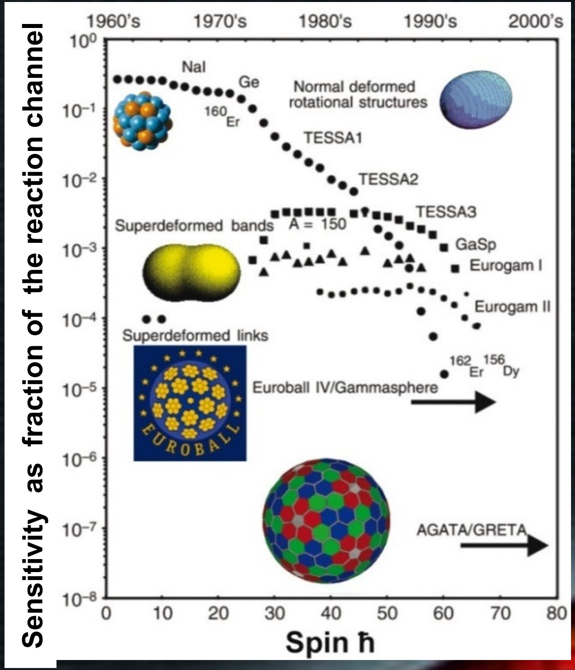
The AGATA project





- 180 (60 triple-clusters) 36-fold segmented crystals
- Amount of germanium: 362 kg
- Solid angle coverage: 82 %
- Singles rate >50 kHz
- Efficiency: 43% (M_g=1) , 28%
- Peak/Total: 58% (M_g=1), 49% (M_g=30)
- Angular Resolution: ~1º

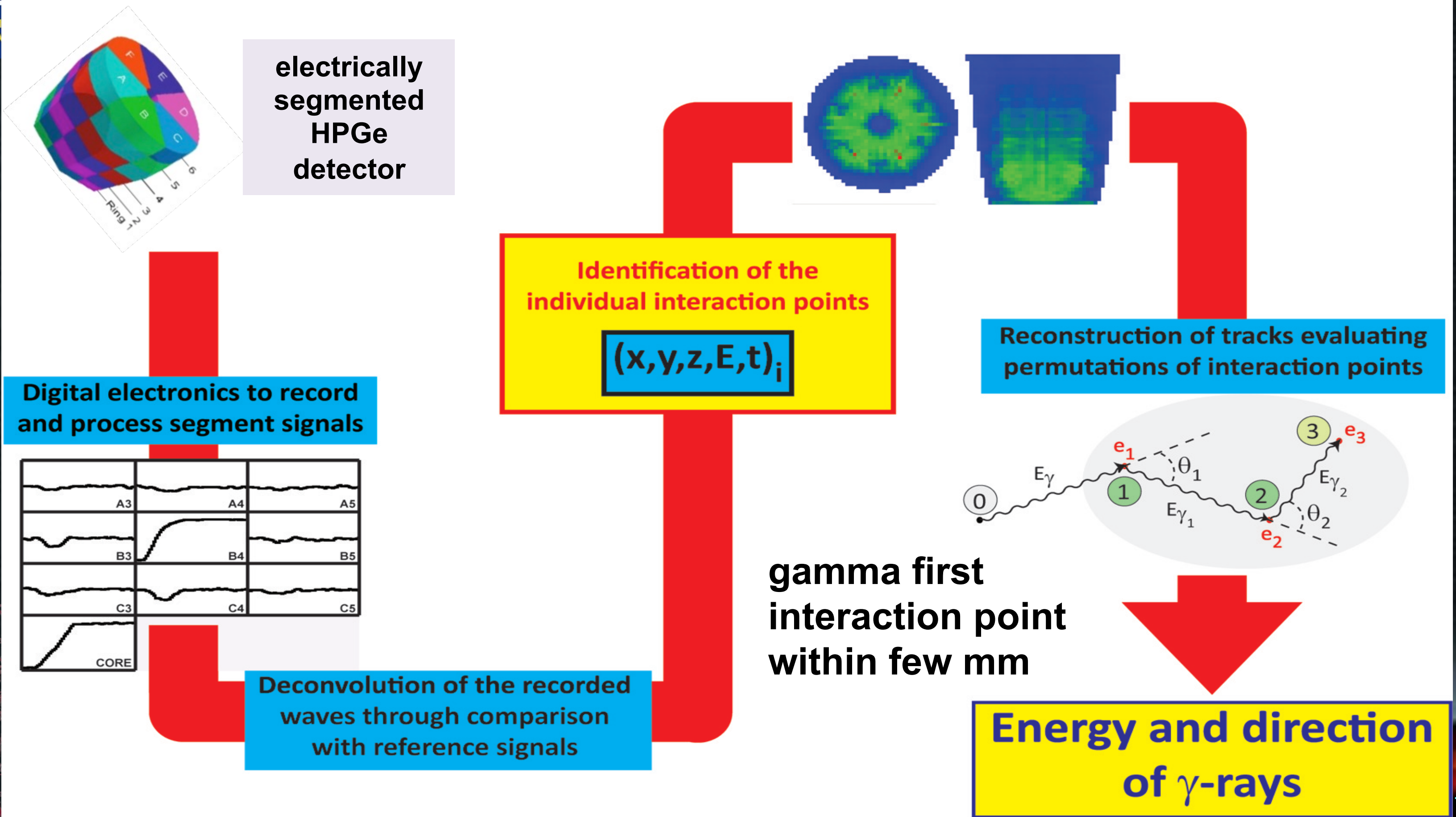




<u>Combination of:</u>

- ❑ segmented detector
- ❑ pulse shape analysis
- ❑ tracking the γ-ray
- ❑ digital electronics

The AGATA concept



courtesy of C. Michelagnoli

AGATA Physics Campaigns

Demonstration phase at **LNL** and Physics Campaign

Coupled to the magnetic spectrometer PRISMA

Construction phase and Physics Campaigns

GSI

Fast radioactive beams coupled to Lycca

GANIL

Coupled to VAMOS, NEDA/N-Wall, VAMOS g.f.m., MUGAST

LNL 2010-2011 → **GSI 2012-2014** → **GANIL 2015-2019**

AGATA at GANIL

The experimental methods

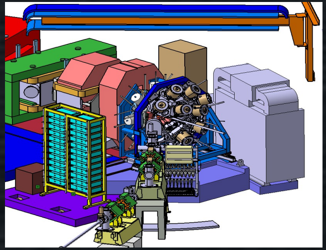
GANIL beams

High intensity stable beams up to ^{238}U

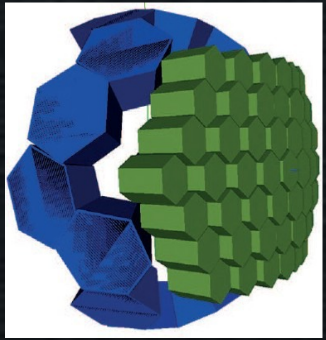
- Multi-nucleon transfer
- Fusion-fission
- Fusion-evaporation

Radioactive SPIRAL1 beams

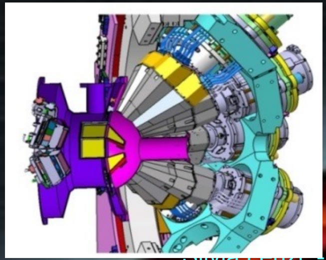
- Coulomb excitation
- Transfer reactions



VAMOS



NEDA



MUGAST

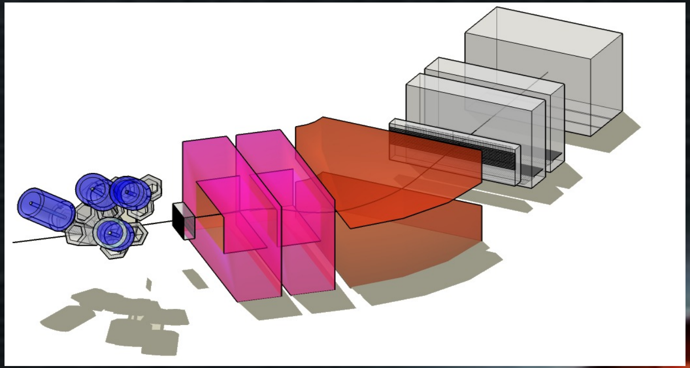
AGATA Physics Campaign in GANIL

The Campaign has been organized in a bottom-up approach following calls for LoI, discussed in dedicated annual collaboration workshops.

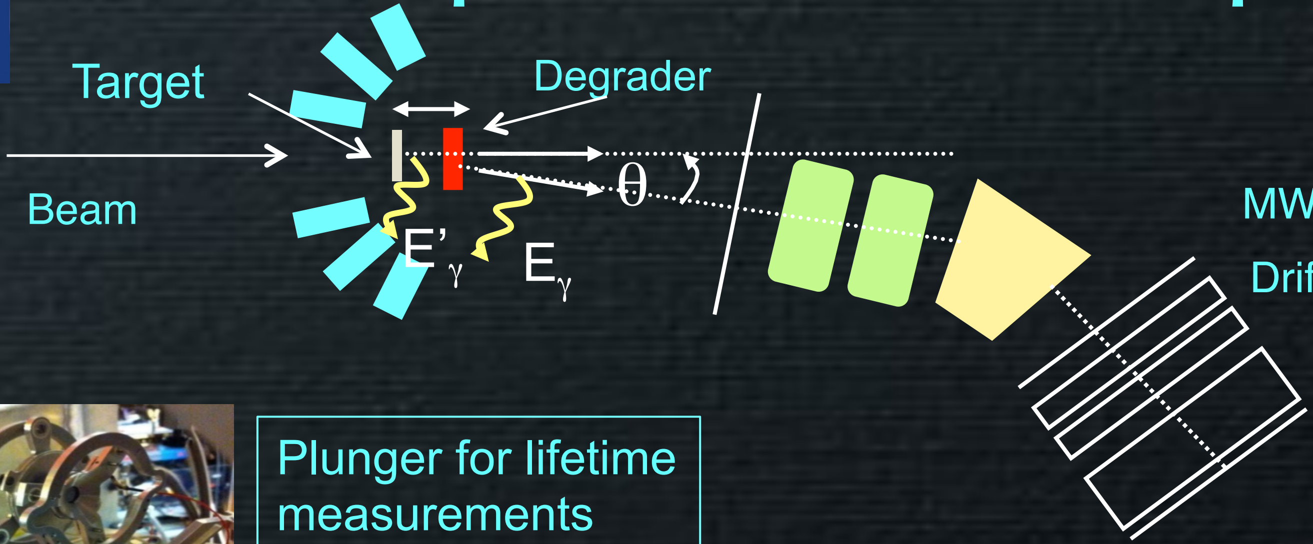
Four main setups (campaigns) have been identified:

- VAMOS (vacuum)
- NEDA-N-Wall + DIAMANT
- MUGAST (SPIRAL1 beams)
- VAMOS (gas-filled)

First Campaign AGATA+VAMOS



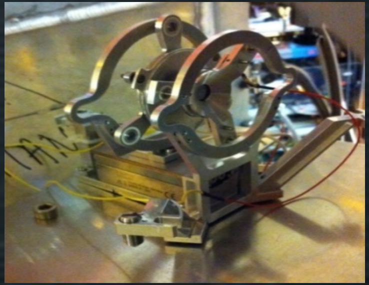
Experimental setup



MWPPAC - ToF

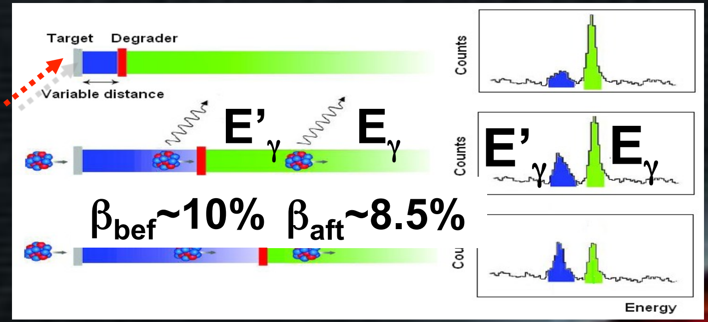
Drift chambers – x,y,θ,ϕ

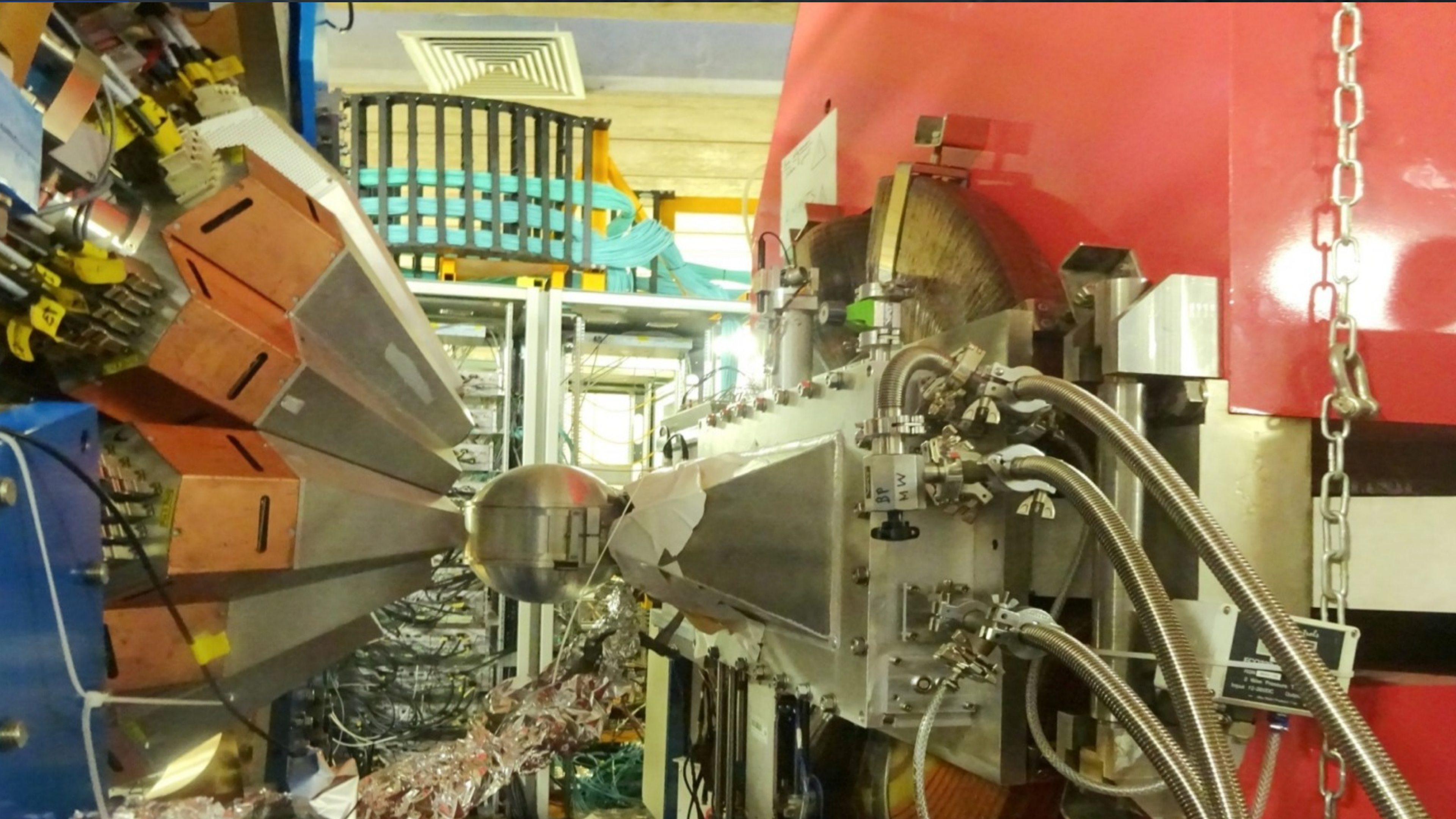
Ionisation chambers- ΔE, E_{res}



Plunger for lifetime measurements

Lifetime is related to the ratio of the yields between the two peaks

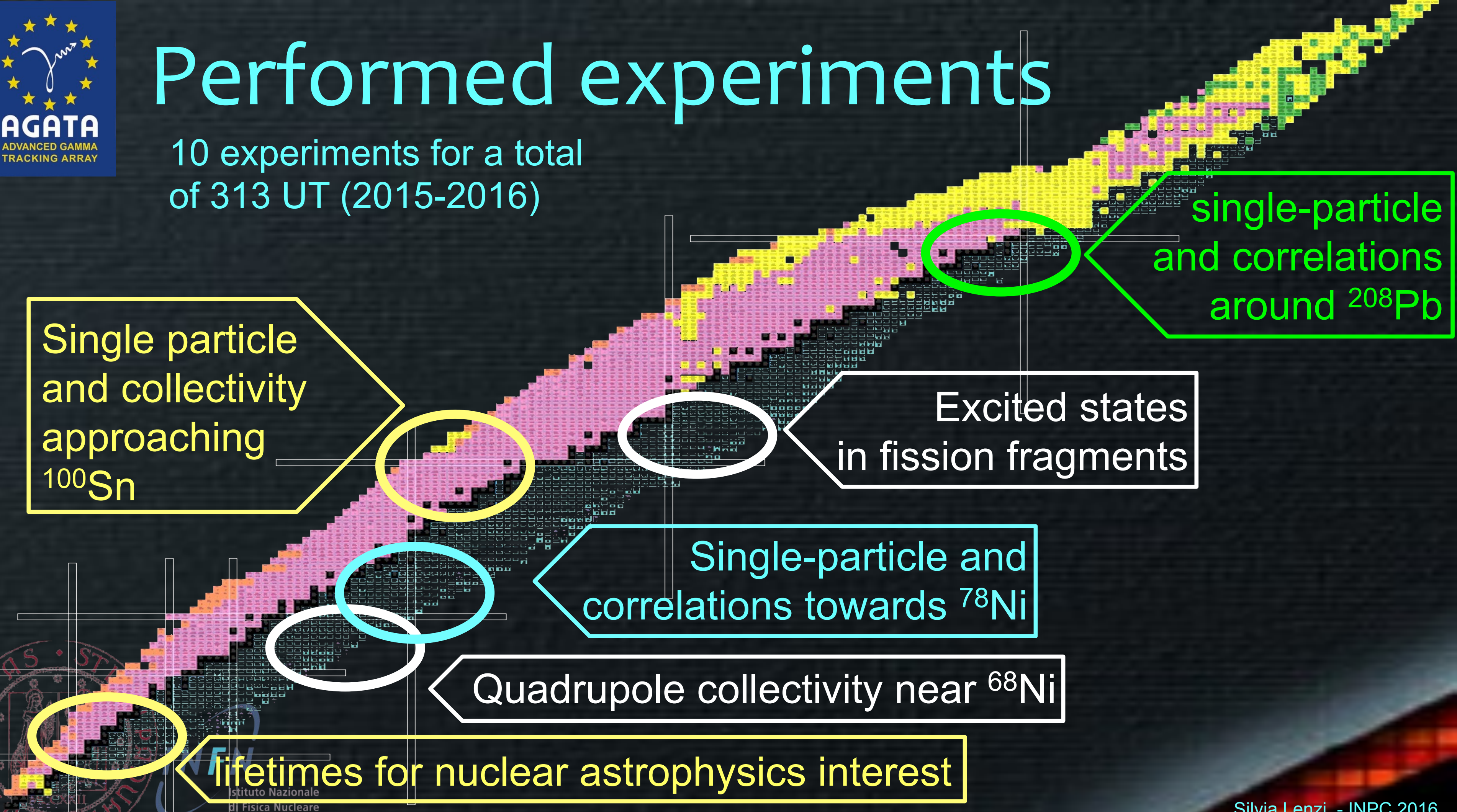


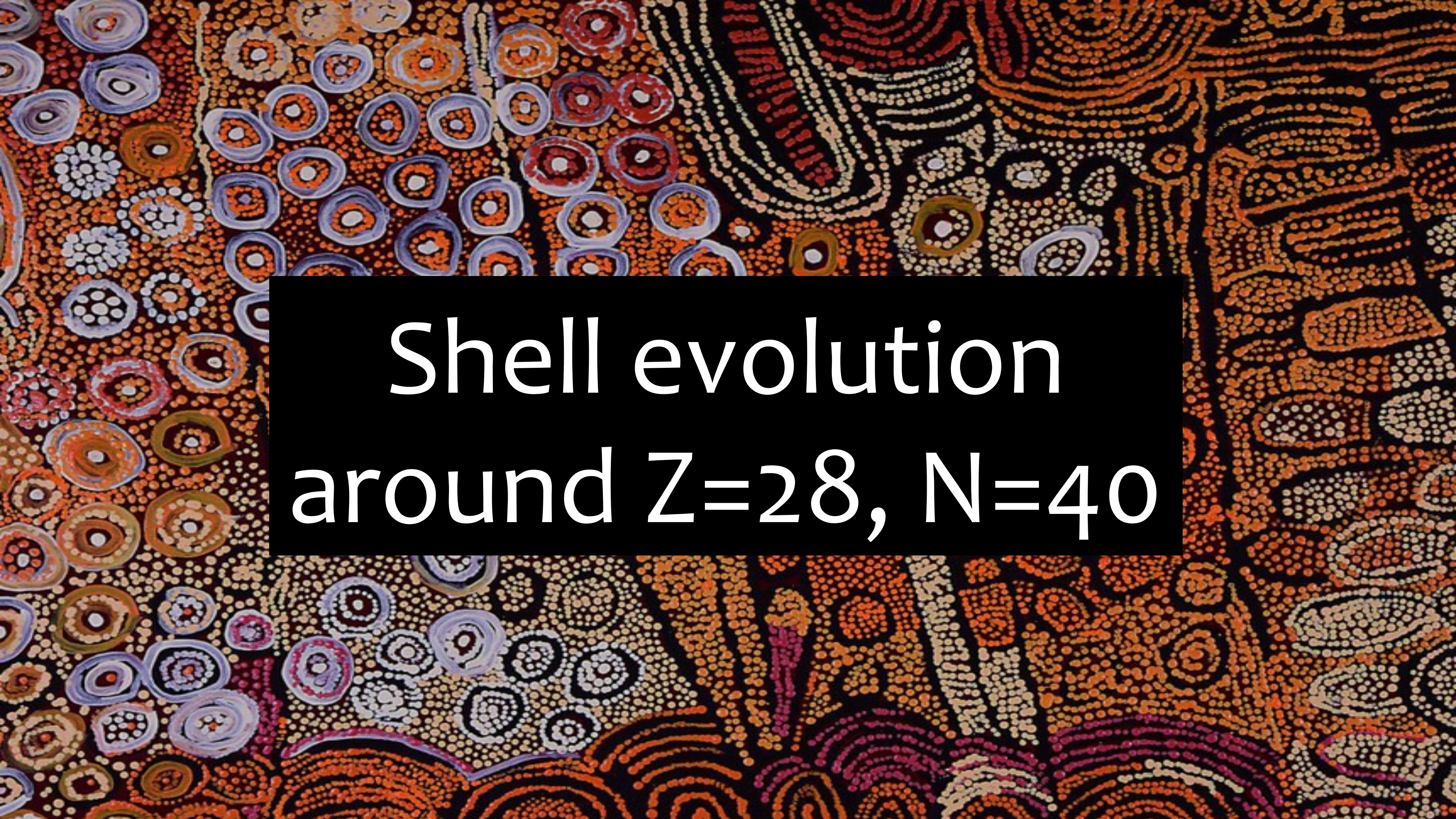


AGATA
ADVANCED GAMMA
TRACKING ARRAY

Performed experiments

10 experiments for a total of 313 UT (2015-2016)

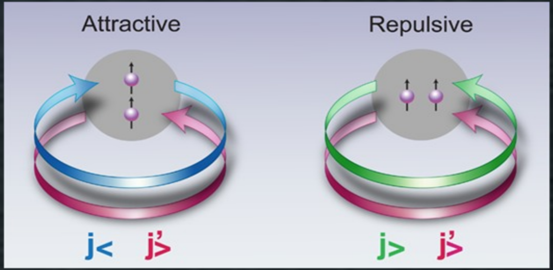


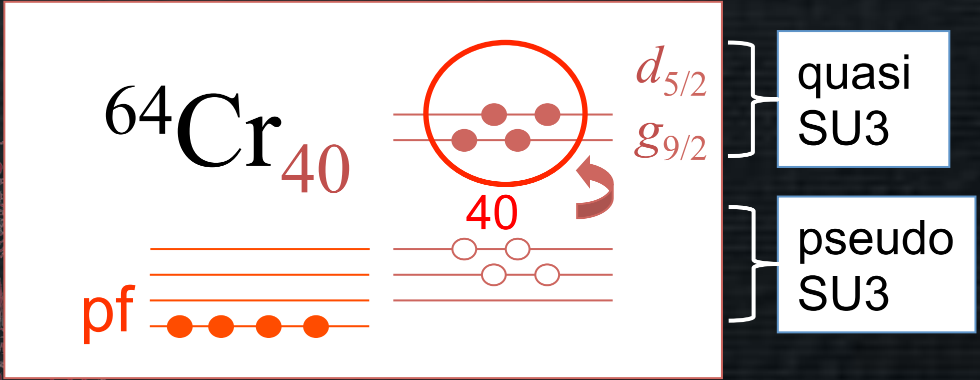


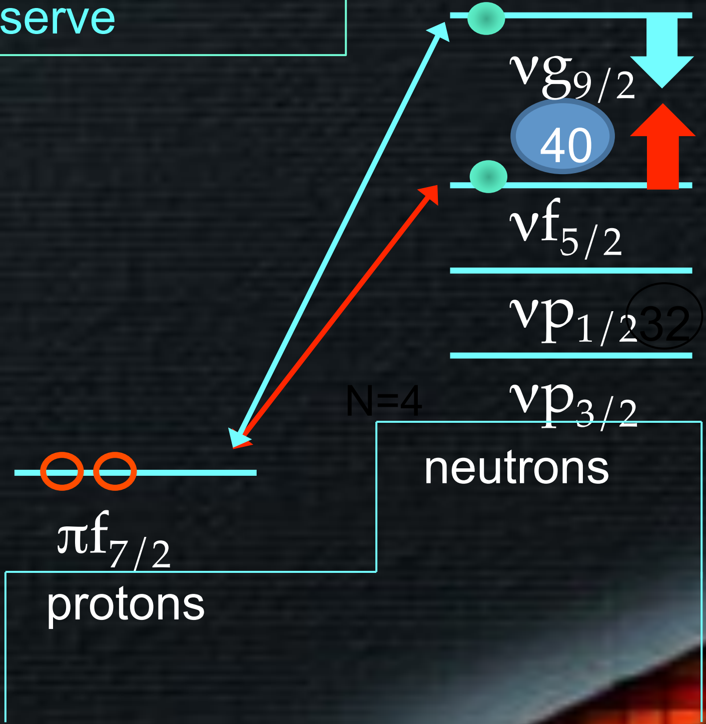
Shell evolution around Z=28, N=40

Shell evolution around N=40

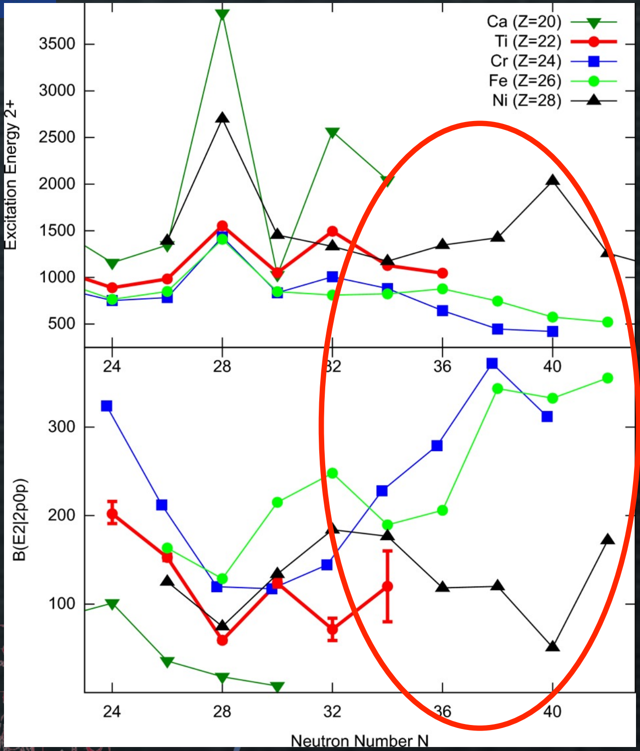
It is the interplay of the monopole terms of the interaction with multipole terms, like pairing and quadrupole, which determines the different phenomena we observe



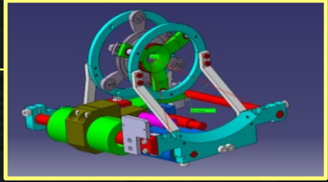




Lifetimes near N=40



Motivation: understanding the development and the trend of deformation in the third island of inversion.

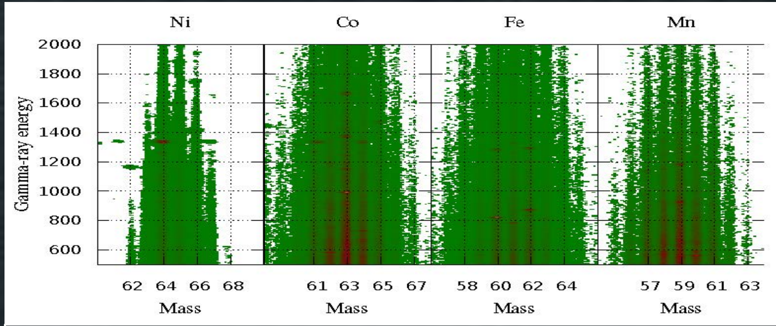


Scarce information on transition probabilities and lifetimes of J>2 states in Cr and Fe

Several nuclei of interest in the region:
Ti, Co (shape coexistence),
Mn no information on lifetimes so far

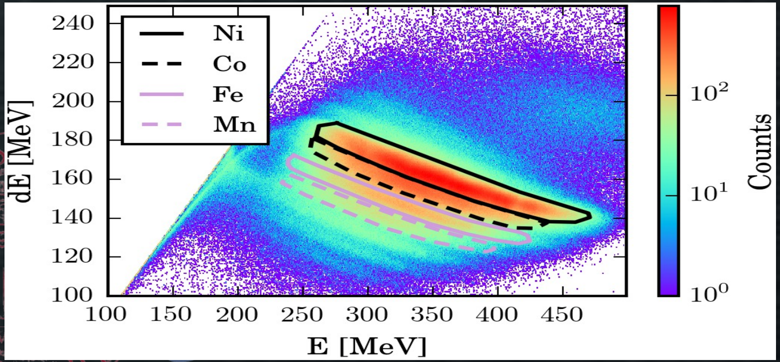
Comparison with LSSM calculations in the fpgd model space

Lifetimes in Mn, Fe, Co and Ni



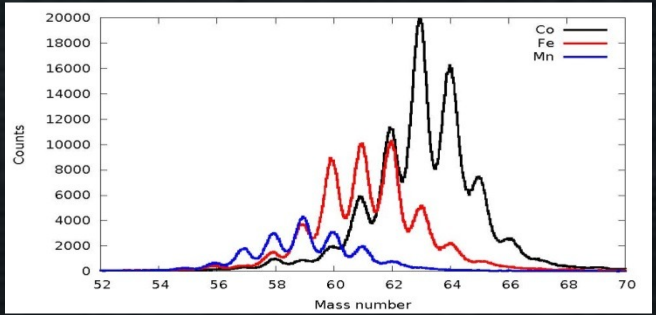
J. Ljungvall *et al.*

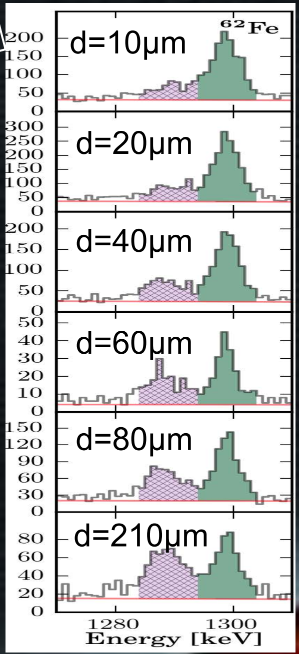
Several new lifetimes in the four isotopic chains



^{62}Fe 4^+ state

Gamma spectra at different distances





Publication in preparation

Courtesy of Joa Ljungvall

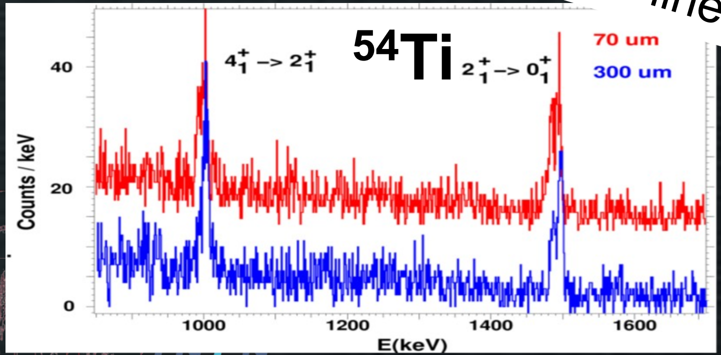
Below and above Z=28

Lifetimes in ^{56}Ti and ^{55}V

Shape evolution: subshell closures and development of deformation

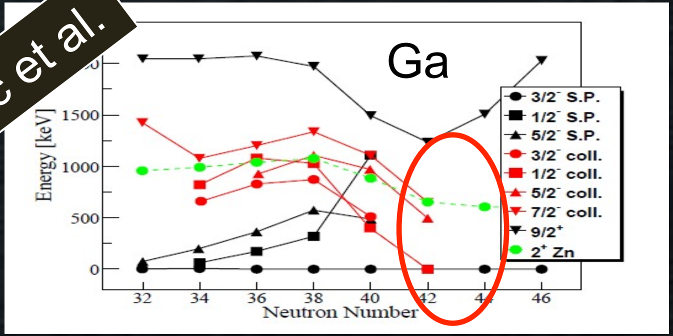
Ch. Fransen et al.

on-line spectra



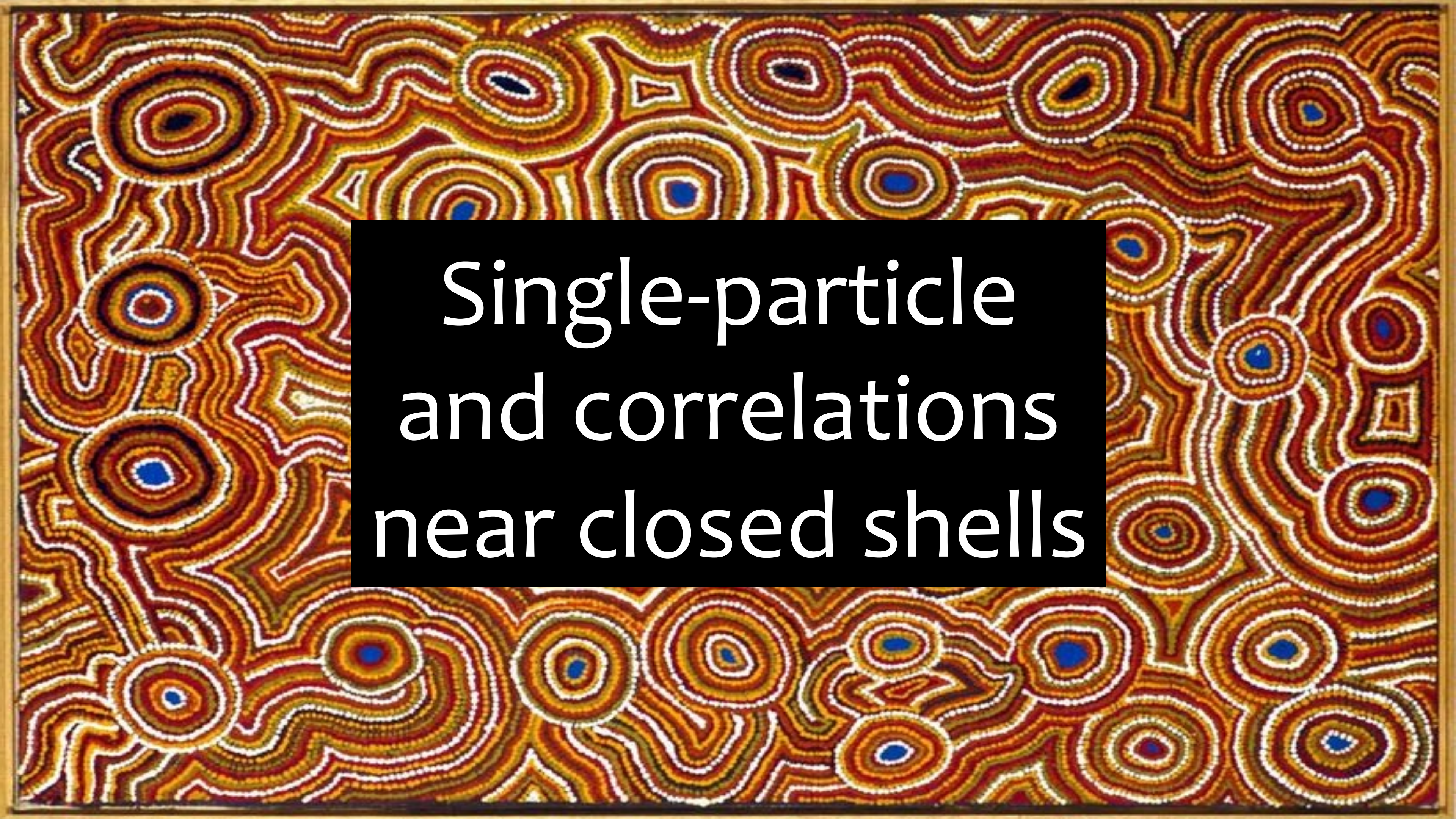
Lifetime in Ga and Zn

I. Celikovic et al.



- lifetime of the 5/2- state in ^{73}Ga decaying to a "degenerate" g.s
- mapping collectivity changes towards N=50

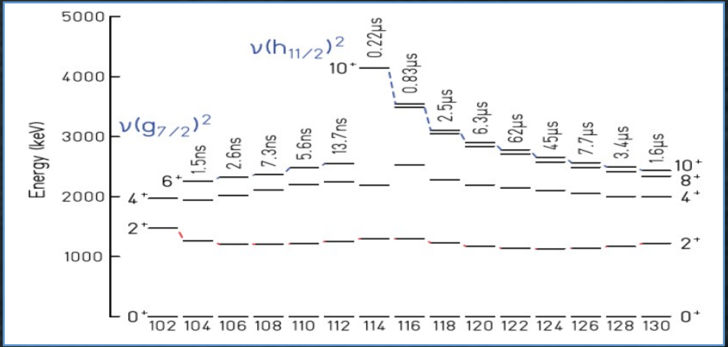
Courtesy of Christoph Fransen and Igor Celikovic



Single-particle and correlations near closed shells

Towards ^{100}Sn: B(E2)'s in $^{106,108}Sn$

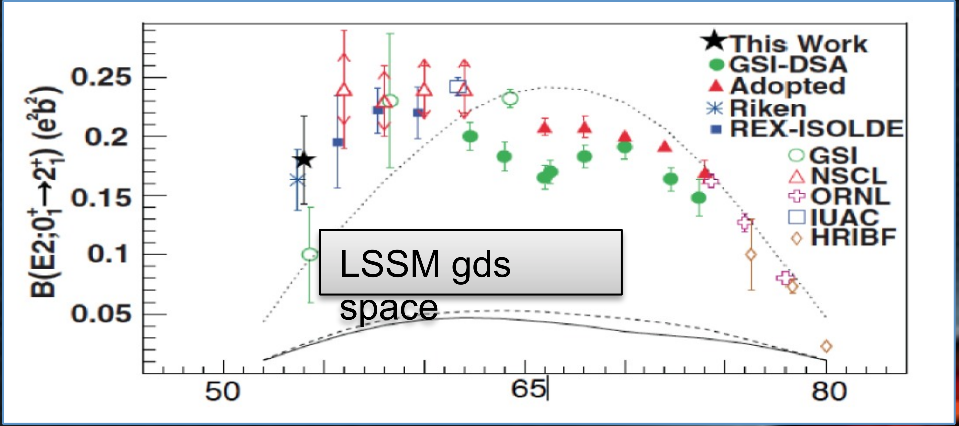
J.J.Valiente-Dobon *et al.*



The behaviour of the B(E2:0⁺→2⁺) depart from the parabolic behaviour expected from SM calculations in the truncated gds space.

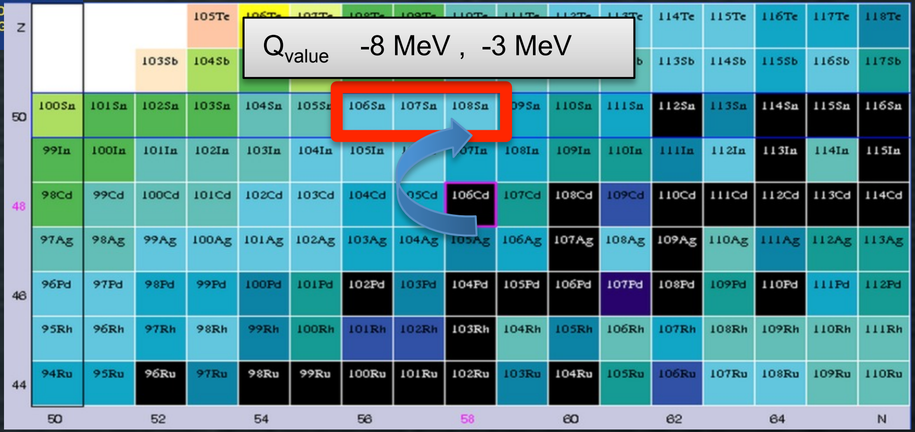
GOAL: Measuring the lifetime of the 2⁺ states with less than 5% error to constrain the models.

First lifetime measurement with plunger device in this region

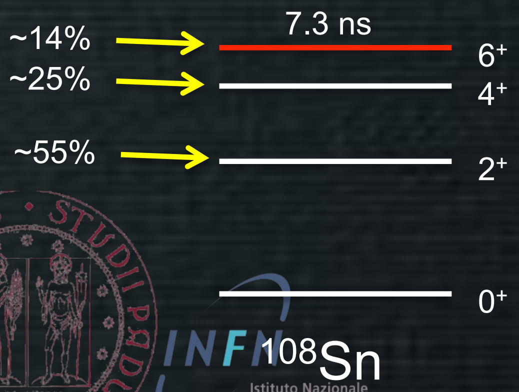


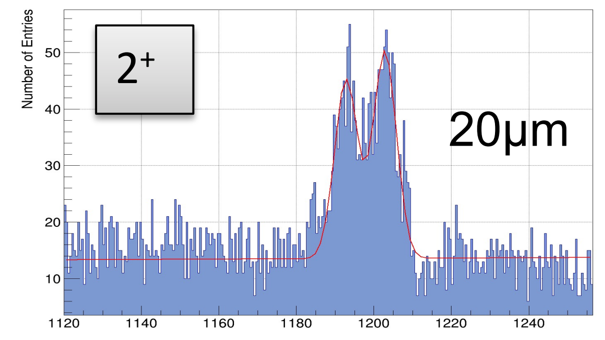
A.M. Bader et al., PRC **88**, 051301(R) (2013)

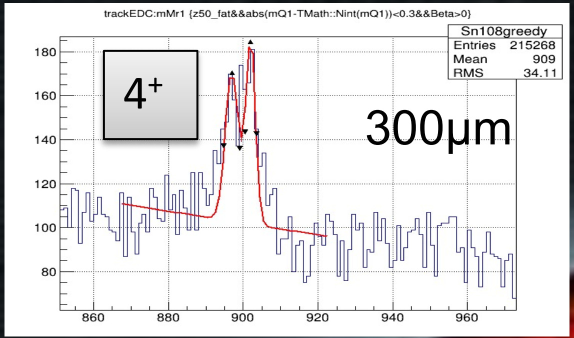
Online plunger spectra



Experimental method: proton-rich populated in multinucleon transfer reactions to selectively populate states below the isomers.





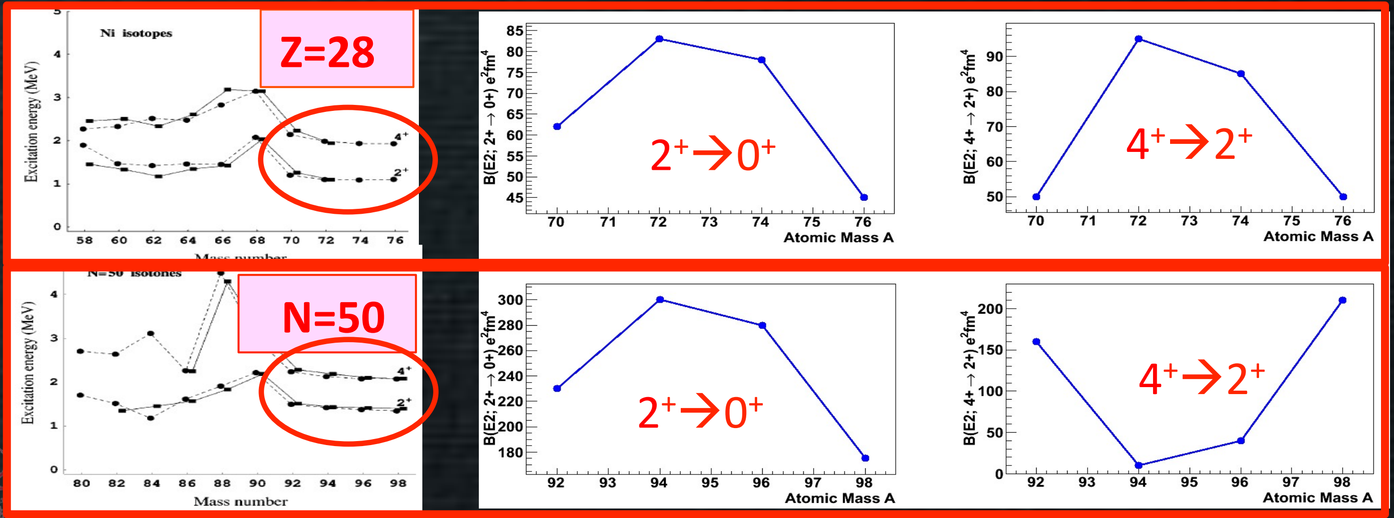


Courtesy M. Siciliano and J.J. Valiente-Dobon

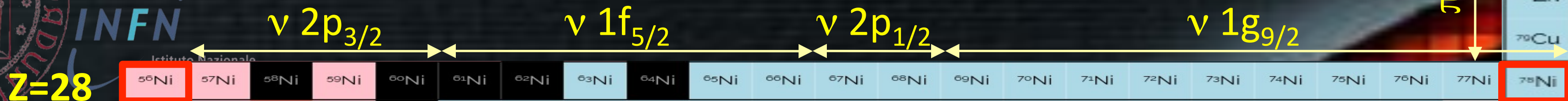
Seniority in N=50: ^{92}Mo and ^{94}Ru

C.Domingo-Pardo *et al.*

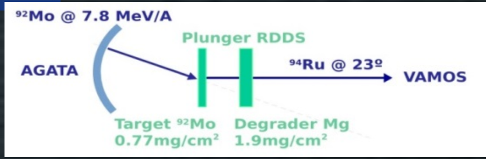
Goal: measuring the transition probabilities for N=50 isotones and compare with the Z=28 isotopes



A.F. Lisetskiy et al., EPJ A 25 S01 (2005)

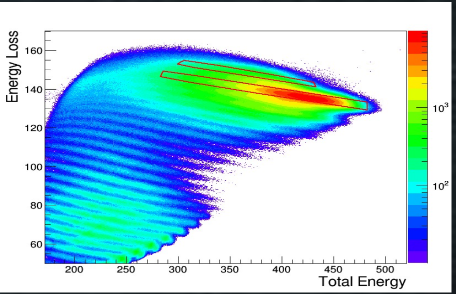


Preliminary results

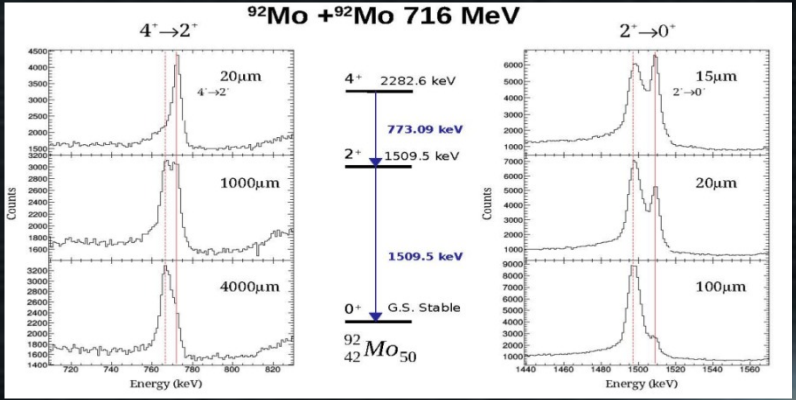


Lifetimes have been obtained for the $2^+ \rightarrow 0^+$ and $4^+ \rightarrow 2^+$ transitions in ^{92}Mo and ^{94}Ru

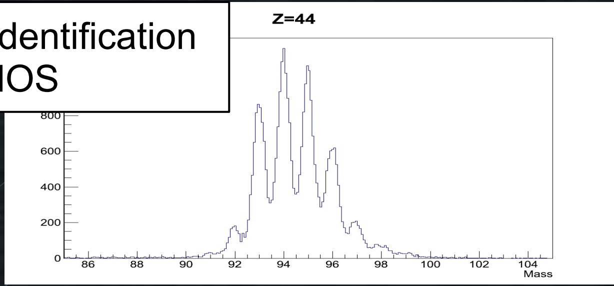
Z-identification in VAMOS



Online spectra for ^{92}Mo

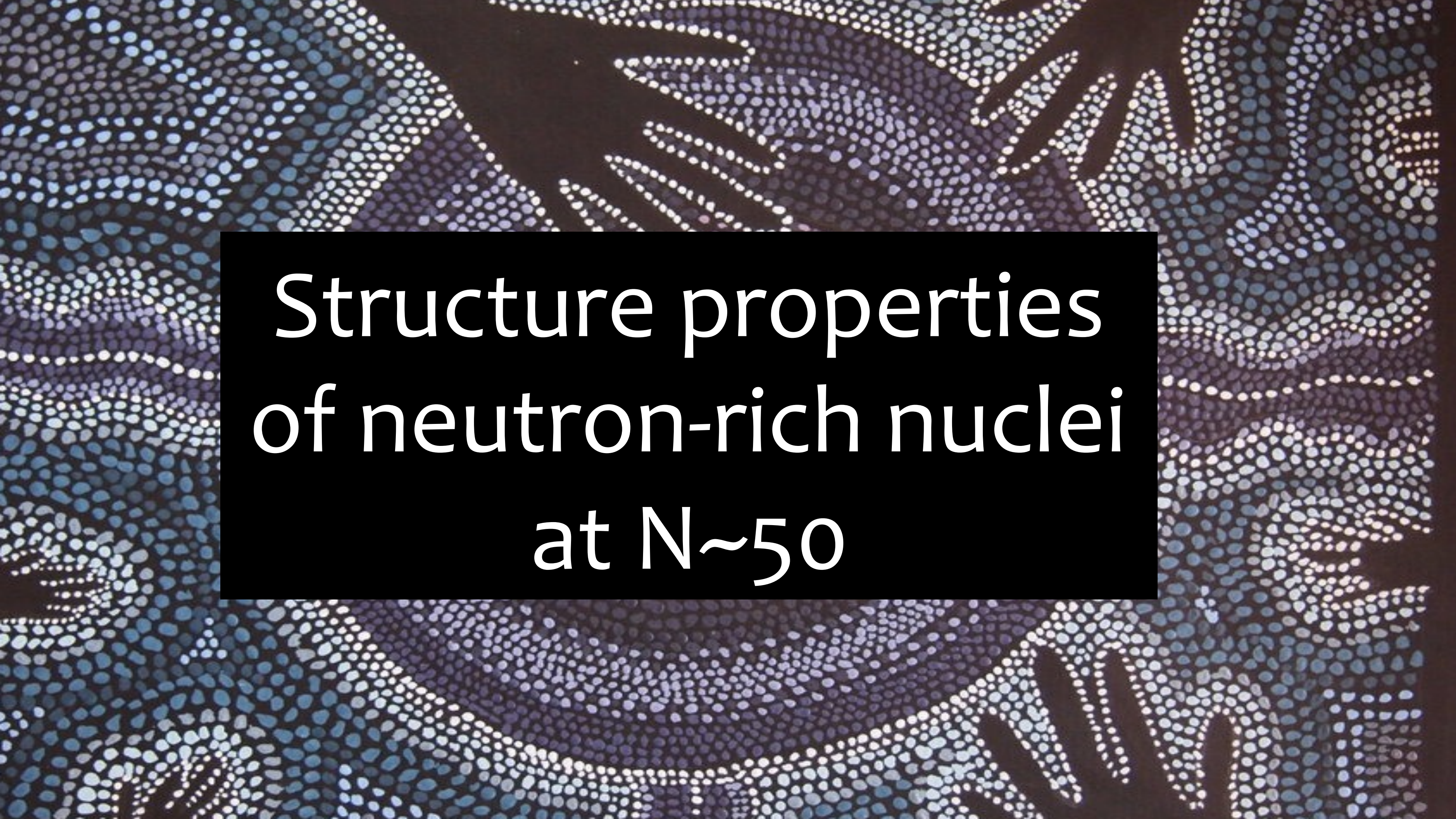


mass-identification in VAMOS



Analysis in progress!

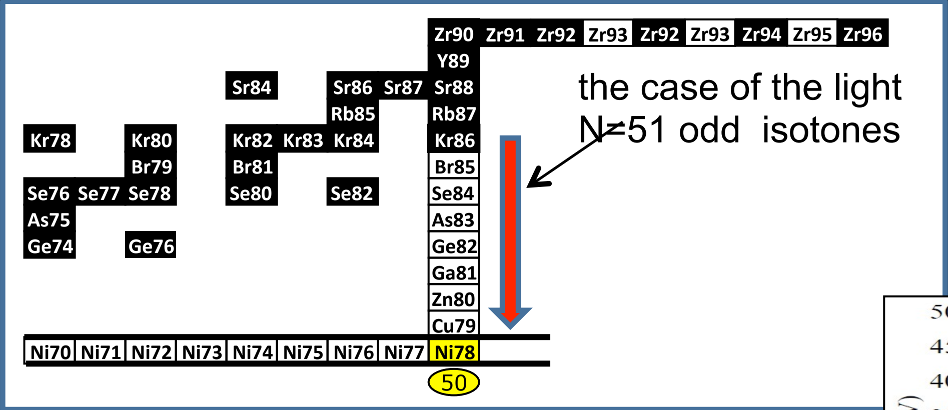
Courtesy of R. Perez



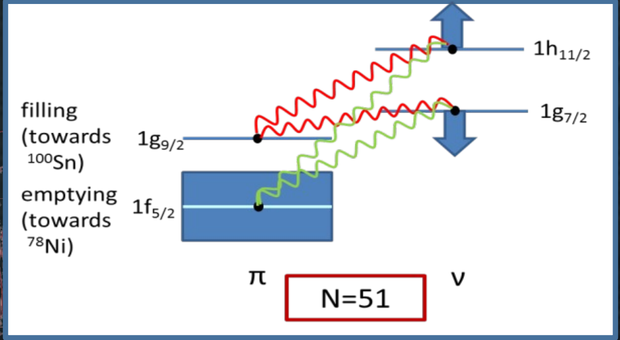
Structure properties of neutron-rich nuclei at N~50

Neutron structure above ^{78}Ni

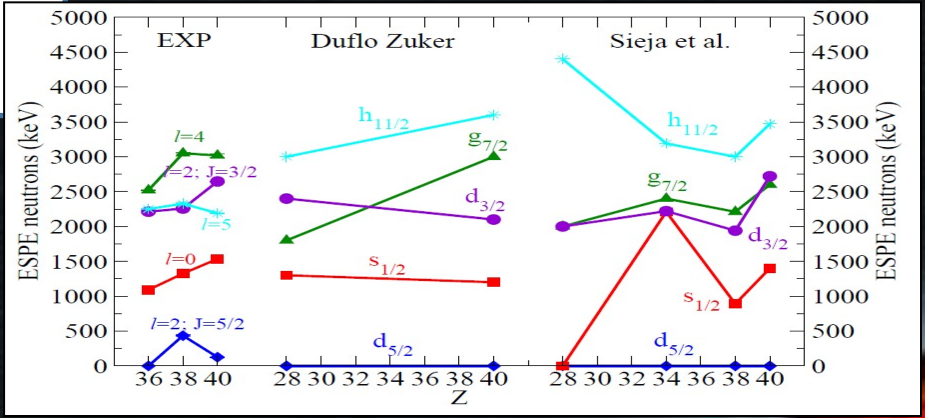
D. Verney *et al.*



Motivation: Understanding the single-particle evolution above N = 50 towards ^{78}Ni



Effective s.p. energies

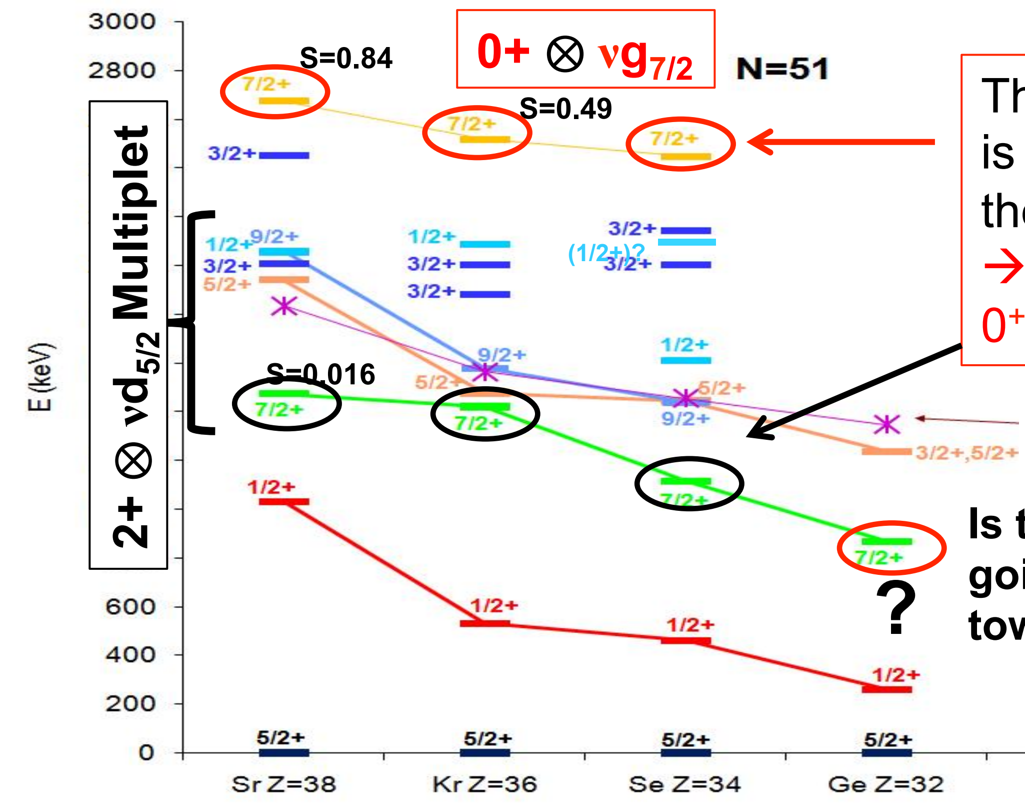


D. K. Sharp et al., PRC **87**, 014312 (2013)

J. Duflo and A.P. Zuker, PRC **59**, R2347 (1999)

K. Sieja et al., PRC **79**, 064310 (2009)

Nature of the 7/2$^+$ states



The 7/2+ state stemming from $\nu g_{7/2}$ is predicted to become yrast along the N=51 line towards ^{79}Ni

→ distinguish between 7/2$^+$ from $0^+ \otimes g_{7/2}$ and core-coupled $2^+ \otimes d_{5/2}$

Is the $g_{7/2}$ strength going down in energy towards ^{79}Ni ?

Courtesy of F. Didierjean and A. Gottardo

Lifetime measurements in N=51

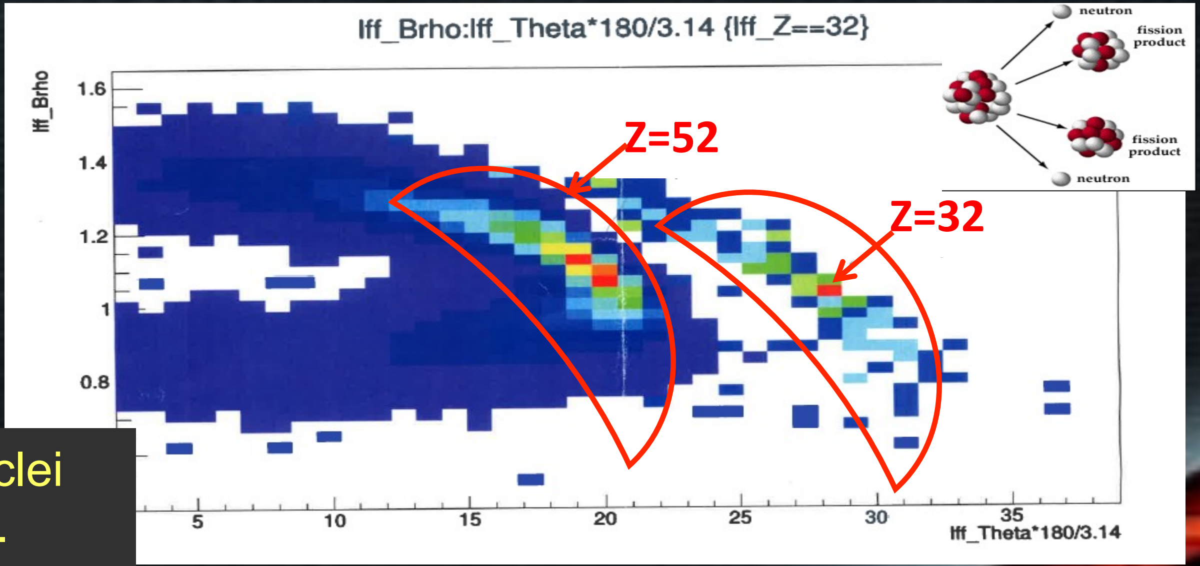
It is relatively easy to distinguish the 2 configurations by lifetime measurements :

$[2^+ \otimes d_{5/2}]\ 7/2_1$	short lived	2 orders of magnitude difference
$[0^+ \otimes g_{7/2}]\ 7/2_1$	long lived	

Fusion-fission reaction $^{238}U + ^{9}Be$

Magnetic spectrometer placed at large angle to select the lowest mass region.

UNIQUE opportunity at GANIL!



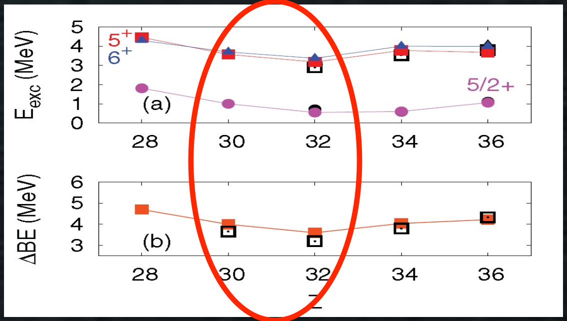
Lifetime in ^{83}Ge and other nuclei in the region can be obtained. Analysis in progress!

Courtesy of A. Gottardo and F. Farget

Test of Z=28, N=50 gaps in ^{80}Zn and ^{82}Ge

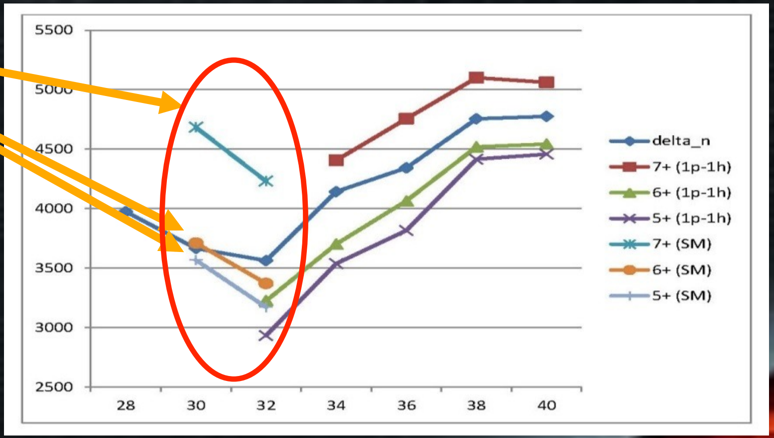
G. Duchene et al

The quenching of the N=50 gap towards ^{78}Ni can be investigated looking at the excitation energy of high-spin states involving particle-hole excitations across the N=50 gap



K. Sieja and F. Nowacki, PRC 85 051301(R) (2012)

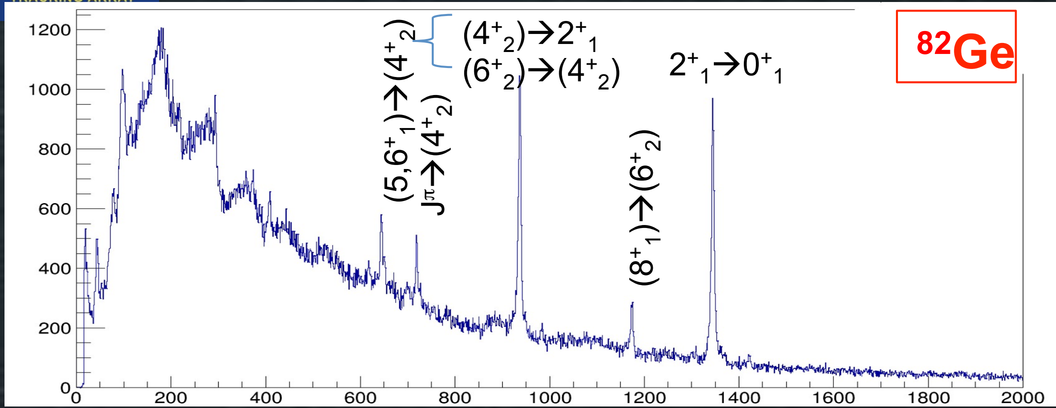
LSSM calculations predict an increase of excitation energy towards ^{78}Ni



Goal: measuring the excitation energy of high spin states: 5,6,7$^+$ in ^{80}Zn and ^{82}Ge

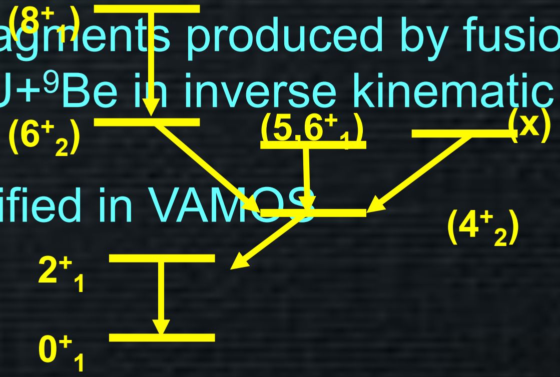
Istituto Nazionale di Fisica Nucleare

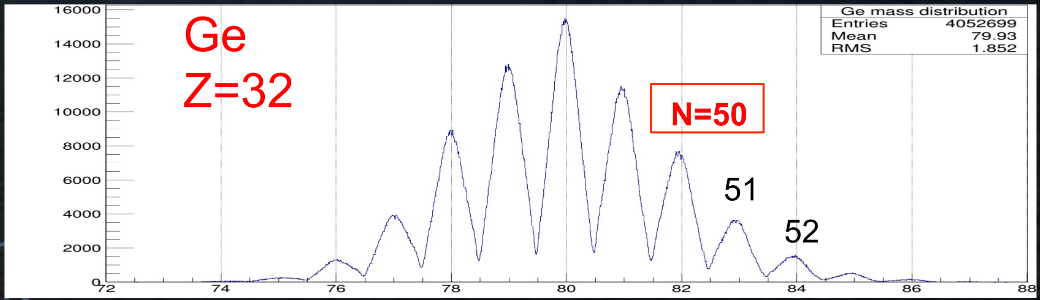
Spectroscopy in the vicinity of ^{78}Ni



ission Fragments produced by fusion-
ssion $^{238}U+^{9}Be$ in inverse kinematic

ully identified in VAMOS





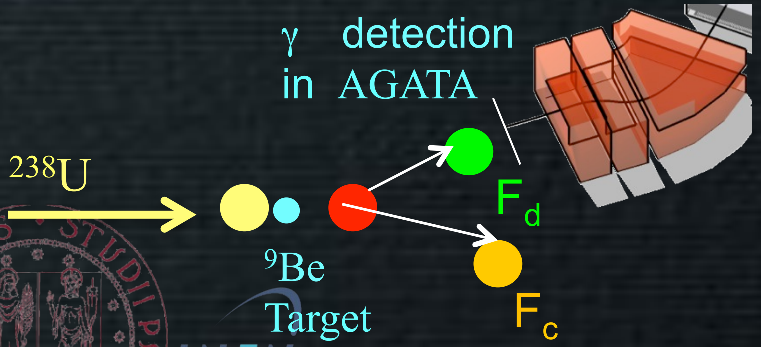
See talk by
J. Dudouet
for further info

courtesy of J. Dudouet et al, Preliminary

Spectroscopy of fission fragments

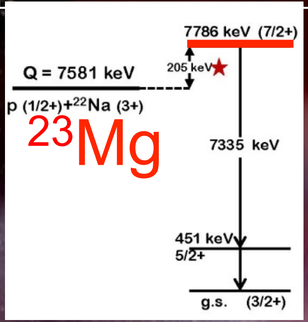
A. Navin, M. Rejmund et al.

Goal: high-spin and isospin spectroscopy. Structure of nuclei around ^{132}Sn



Nuclear Astrophysics

C. Michelagnoli et al.

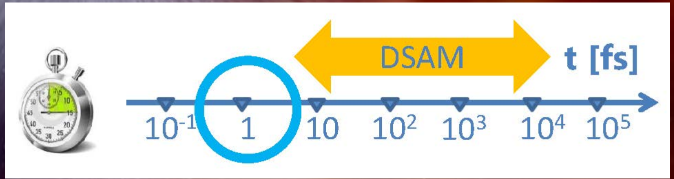


the determination of the rate of destruction of ^{22}Na is crucial for nova models

$^{22}Na(p,\gamma)^{23}Mg$

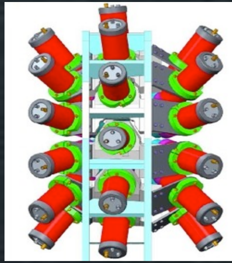
dominated by the resonance at 205 keV above threshold

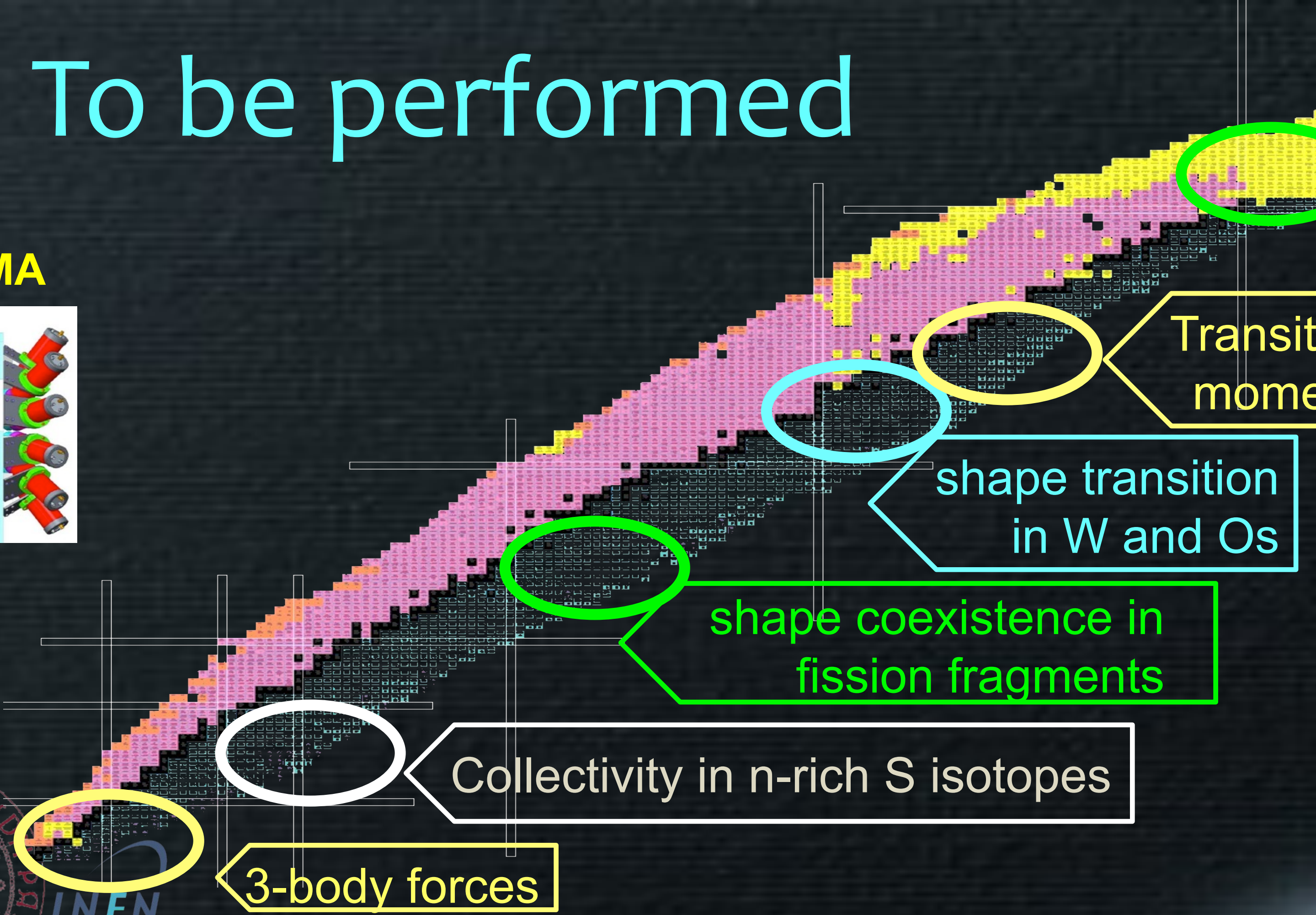
Measurement: lifetime of the 7.786 MeV state in ^{23}Mg, exploiting the position sensitivity of AGATA to push the Doppler Shift Attenuation Method to the limit of its applicability



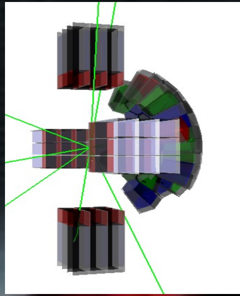
To be performed

FATIMA





PARIS



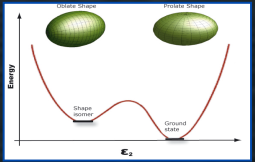
Future campaigns

NEDA/N-Wall campaign 2018

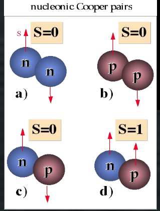
AGATA
ADVANCED GAMMA TRACKING ARRAY

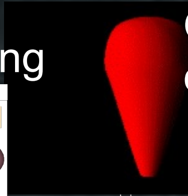
Coupling to the continuum

Shape coexistence



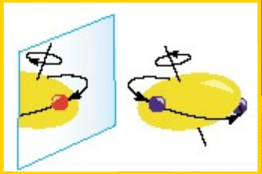
p-n pairing



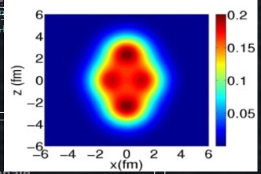


Octupole correlations

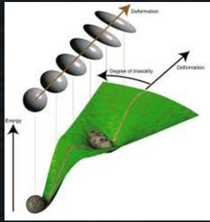
Isospin symmetry breaking



clusterization

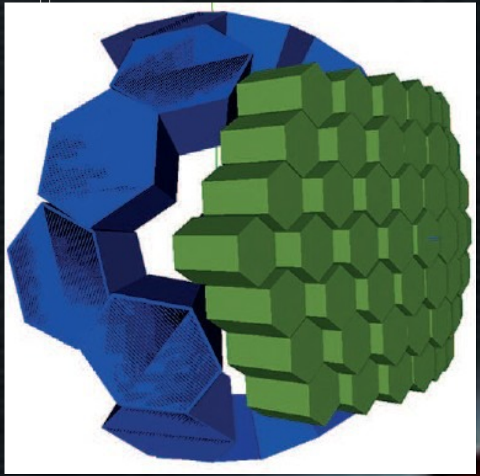


superdef



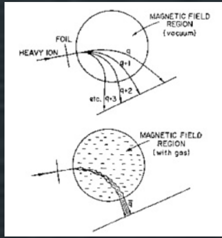
DIAMANT

NEDA+N-Wall

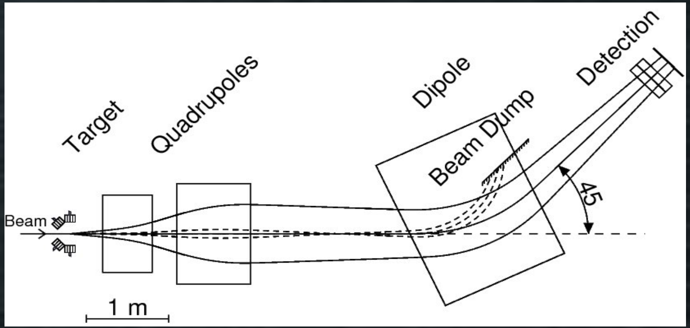


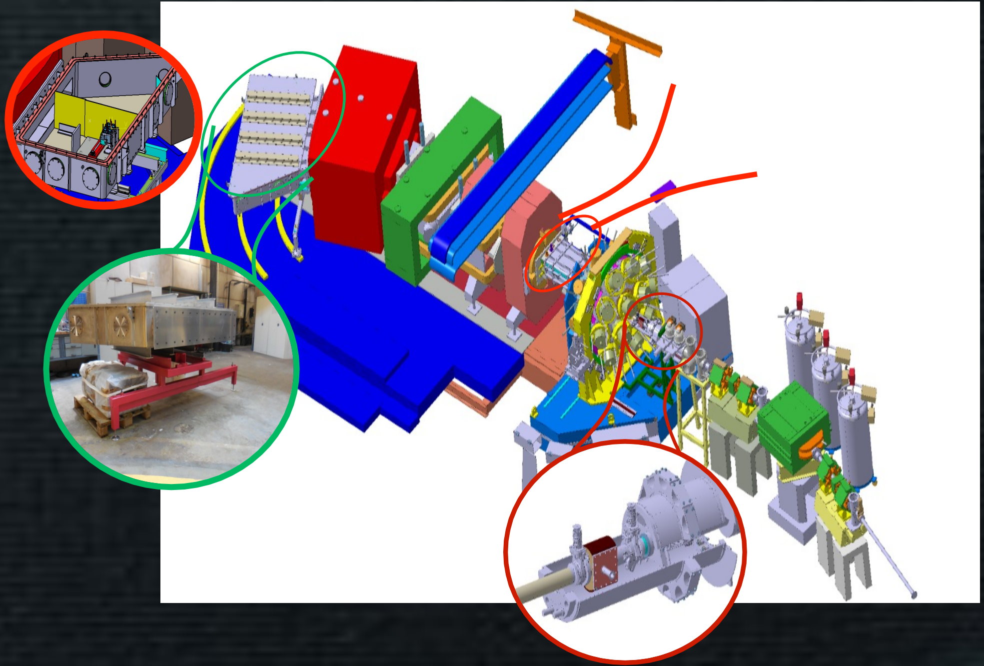
INFN
Istituto Nazionale di Fisica Nucleare

LoI for VAMOS in gas-filled mode



C. Schmitt *et al.*,
NIM A 621 (2010) 558



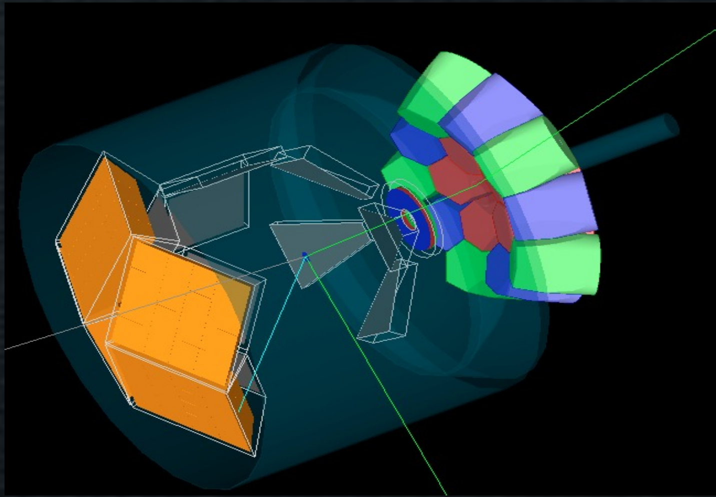


LoI June 2016 to PAC GANIL
31 labs, 180 participants,

Great opportunities for spectroscopy from ^{100}Sn to SHE regions!

LoI for MUGAST + VAMOS

Si array for reaction and structure studies with radioactive beams from SPIRAL1

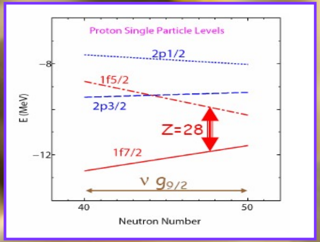


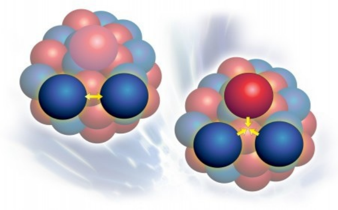
The LoI propose to study:

Nuclear Astrophysics: spectroscopic factors of relevant resonances for nucleosynthesis studies in radiative capture reactions: (6LI,d), (3He,d), (d,p)

Shell evolution:
spectroscopic factors, s.p. energies (d,p), (t,p), p-n pairing, clusterization

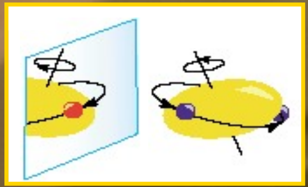
Shell evolution far from stability



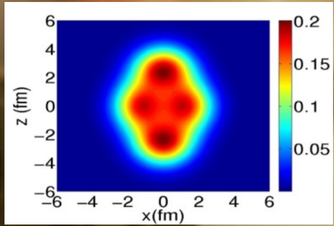


Three-body forces

Isospin symmetry breaking

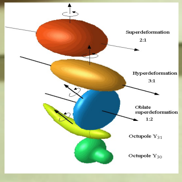


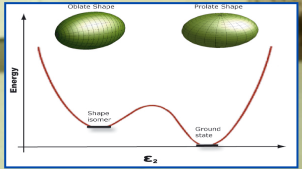
clusterization



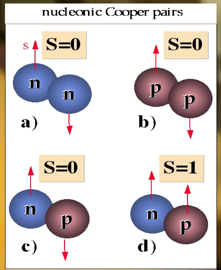
The AGATA Physics Campaign in GANIL offers unique opportunities to study a large variety of nuclear structure properties all along the nuclear chart

Nuclear shapes and coexistence

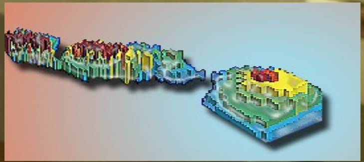




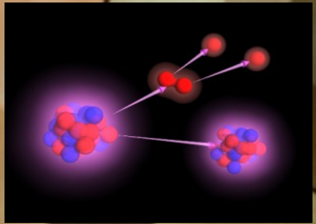
p-n pairing



Super heavy elements



Nuclear Astrophysics



Coupling to the continuum

Thanks to the AGATA Collaboration,
the Management Board leaded by A. Gadea
and specially to the GANIL team leaded by
the project manager Emmanuel Clément

Thank you for your attention