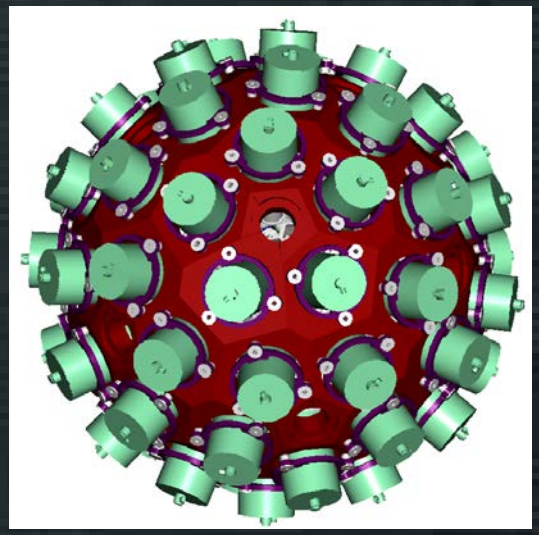
AGATA Campaign at GANIL

Silvia M. Lenzi
University of Padova and INFN

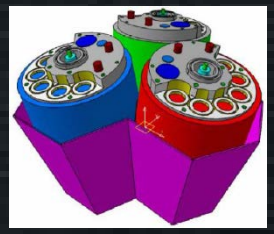
Joint LIA COLL-AGAIN, COPIGAL, POLITA WORKSHOP
26-29 April 2016, LNS Catania

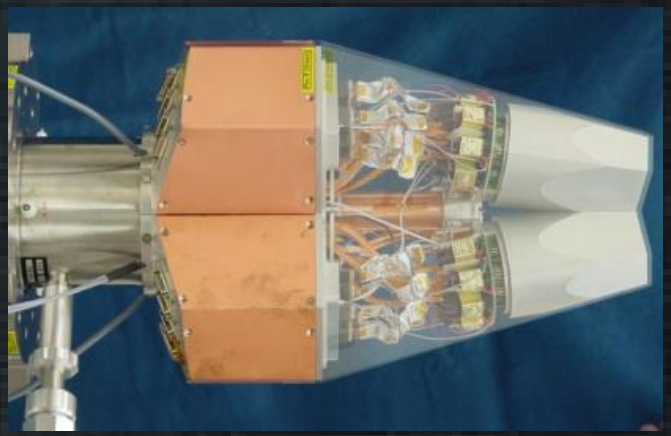
The AGATA project



- 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% (M_g=30)
- Peak/Total: 58% (M_g=1), 49% (M_g=30)
- Angular Resolution: ~1º

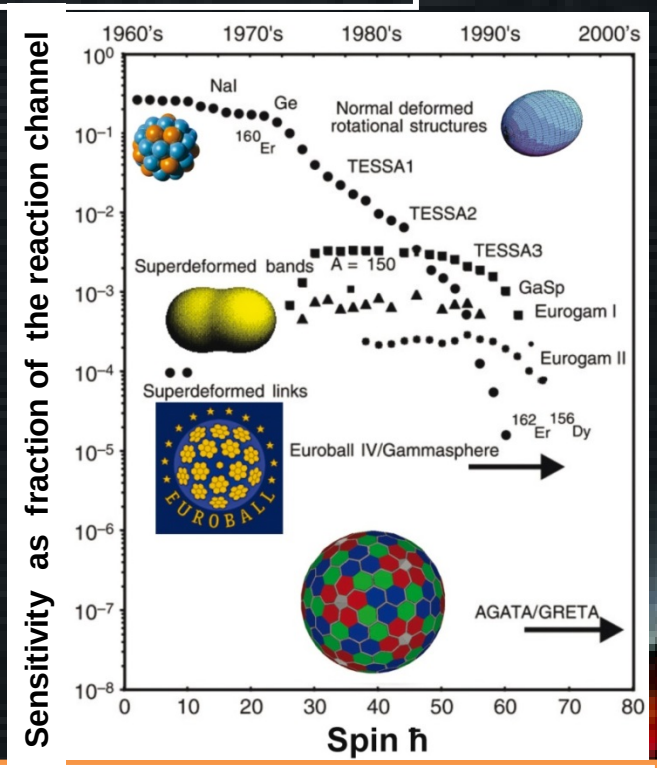
Sant'Agata patron saint of Catania



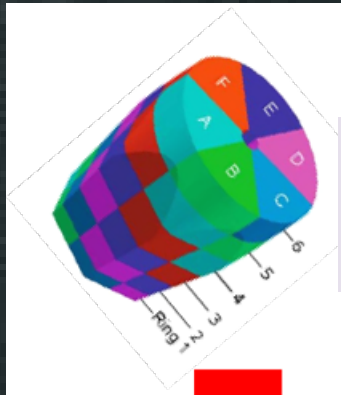


Combination of:

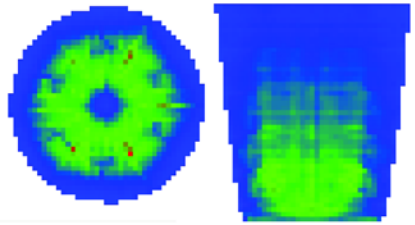
- ❑ segmented detector
- ❑ pulse shape analysis
- ❑ tracking the γ-ray
- ❑ digital electronics



The AGATA concept



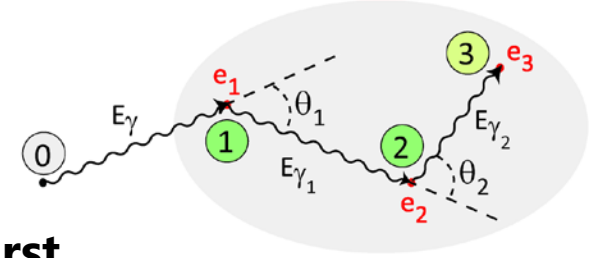
electrically segmented HPGe detector



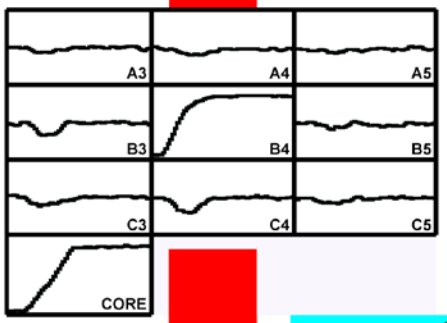
Identification of the individual interaction points

$(x,y,z,E,t)_i$

Reconstruction of tracks evaluating permutations of interaction points



Digital electronics to record and process segment signals



Deconvolution of the recorded waves through comparison with reference signals

gamma first interaction point within few mm

Energy and direction of γ-rays

courtesy of C. Michelagnoli

AGATA Campaigns

Demonstration phase at LNL and Physics Campaign

Construction phase and Physics Campaigns

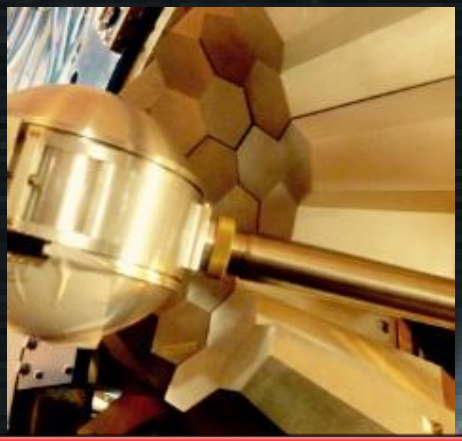
Coupled to the magnetic spectrometer PRISMA

GSI

Fast radioactive beams from FRS coupled to Lycca

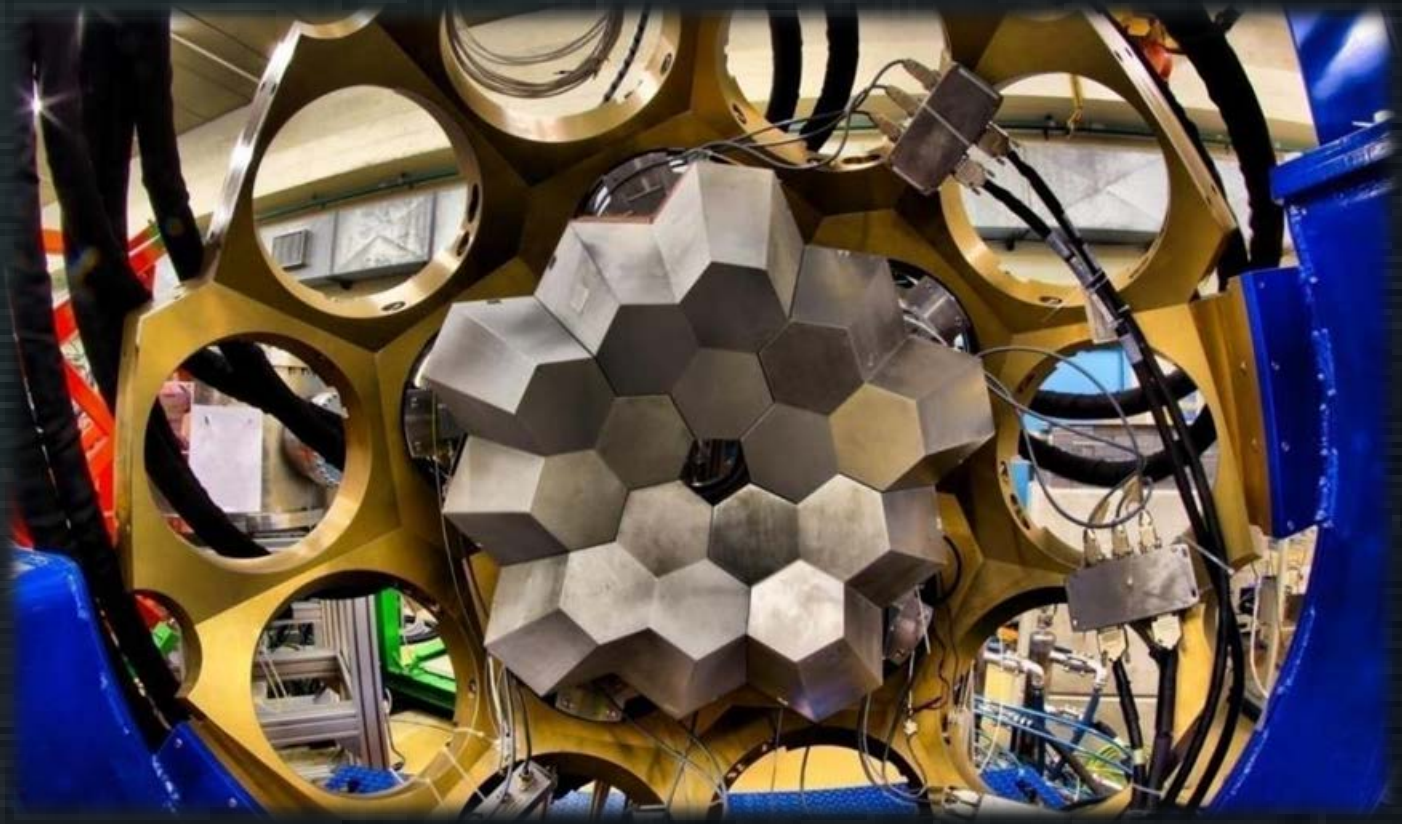
GANIL

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



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

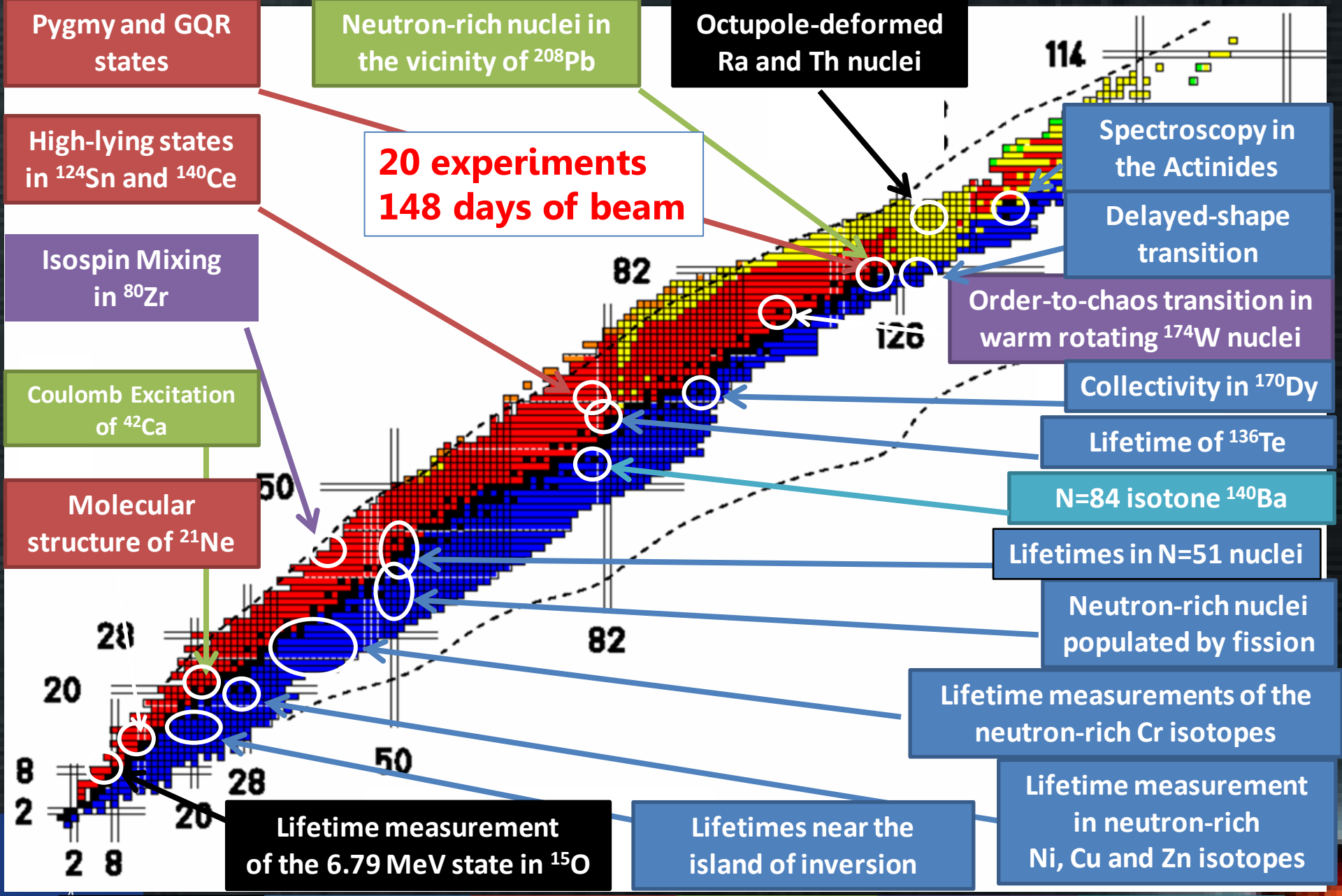
LNL Campaign : AGATA Demonstrator



Coupled to the PRISMA Magnetic Spectrometer

2010-2011

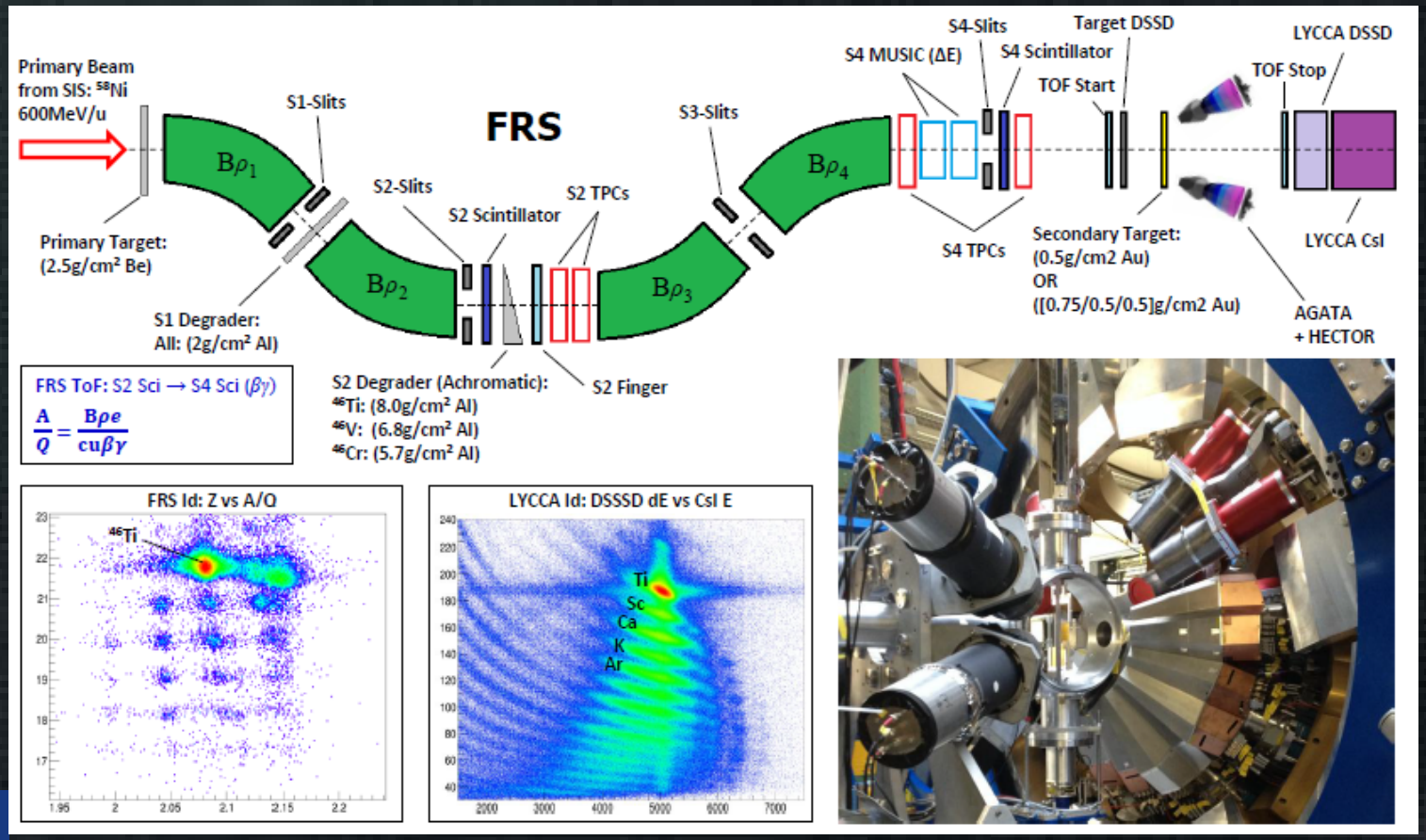
AGATA
ADVANCED GAMMA TRACKING ARRAY



AGATA
ADVANCED GAMMA TRACKING ARRAY

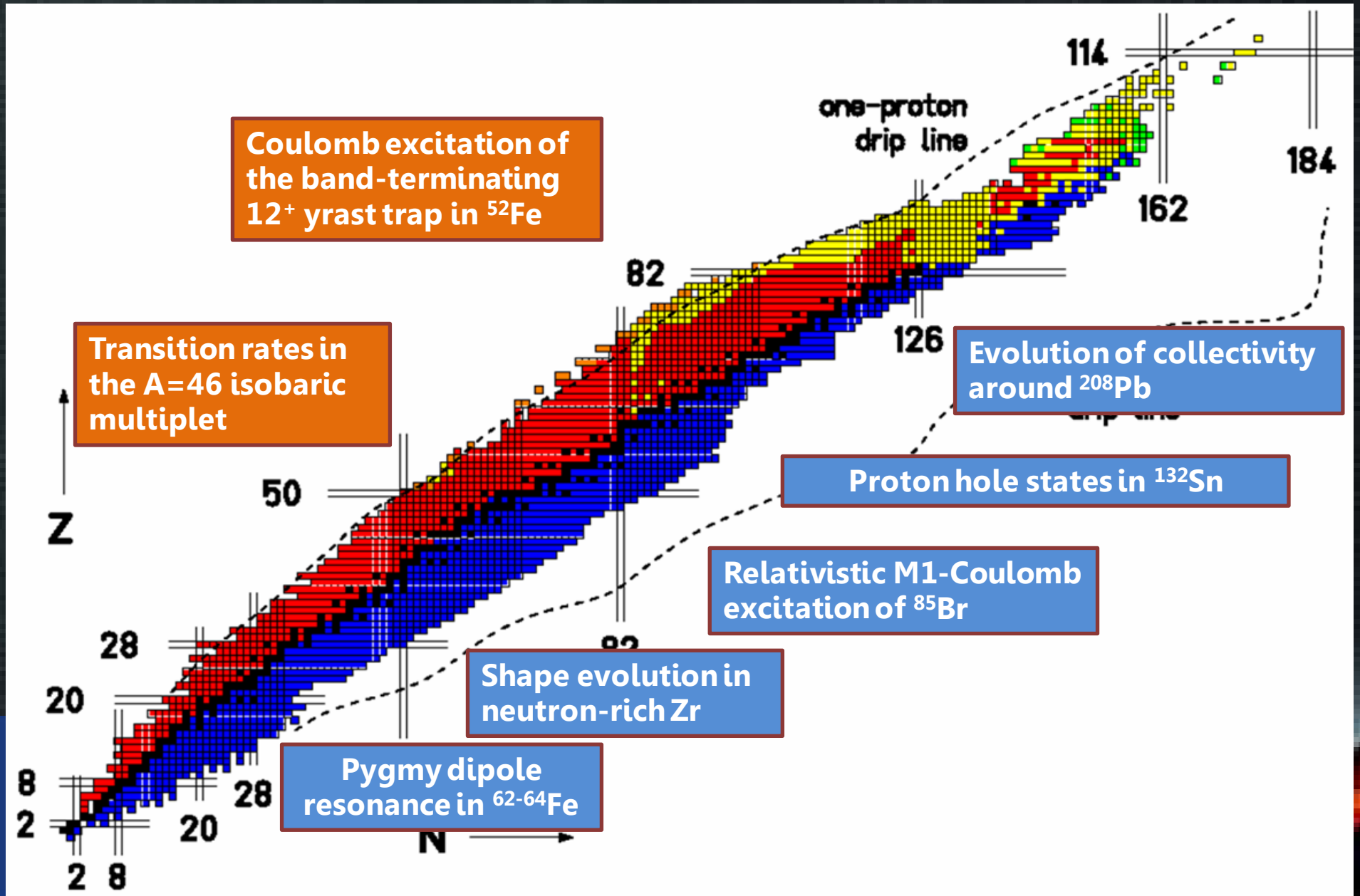
courtesy of D. Mengoni and F. Recchia

The GSI Campaign: Fast radioactive beams



2012-2014

AGATA Experiments in GSI



AGATA@GANIL

2015-2019

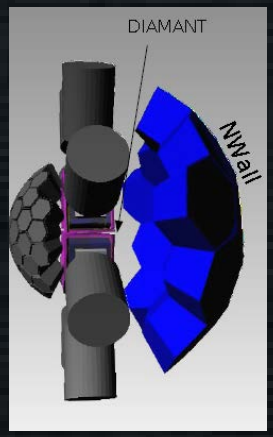
The experimental methods

GANIL beams

High intensity stable beams up to ^{238}U

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

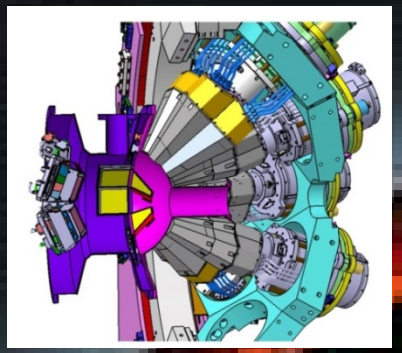
VAMOS



NEDA

Radioactive SPIRAL1 beams

- Coulomb excitation
- Transfer reactions



MUGAST

AGATA
ADVANCED GAMMA TRACKING ARRAY

Physics cases at GANIL

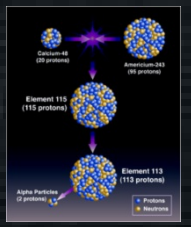
Location of shell gaps and high spin in VHE

Nuclear astrophysics

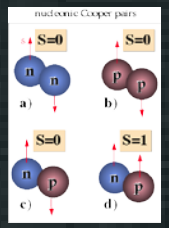
Octupole correlations

Coupling to the continuum

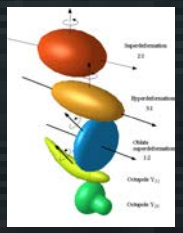
Production and structure of VHE



Enhanced p-n correlations



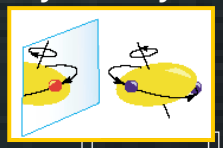
Search for exotic shapes



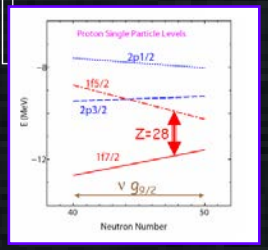
Shape and K isomers

Reaction mechanisms

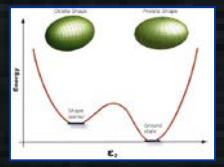
Isospin symmetry



Effective single-particle energies



Shape coexistence



Evolution of magic numbers and deformation

AGATA Physics Campaign

Since 2013 we have organized annual workshops to plan the AGATA Campaign in a bottom-up approach following calls for LoI.

Four main setups have identified on the basis of the LoI

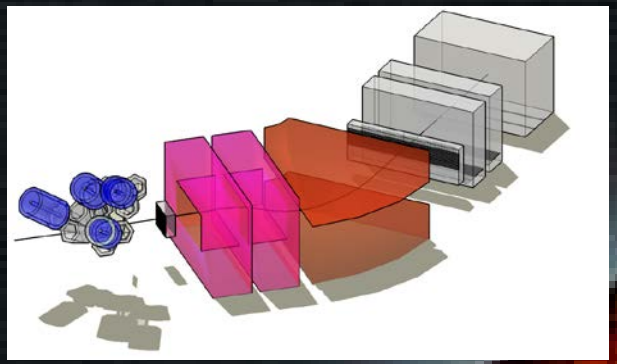
- VAMOS (vacuum)
- NEDA-N-Wall + DIAMANT
- VAMOS (gas-filled)
- MUGAST (SPIRAL1 beams)

Aim of the Workshops is to:

Create the basis for defining the priorities for a detailed scientific program of the campaign

Assess the technical feasibility, constrain the infrastructure and ancillary detectors integration

First Campaign AGATA+VAMOS



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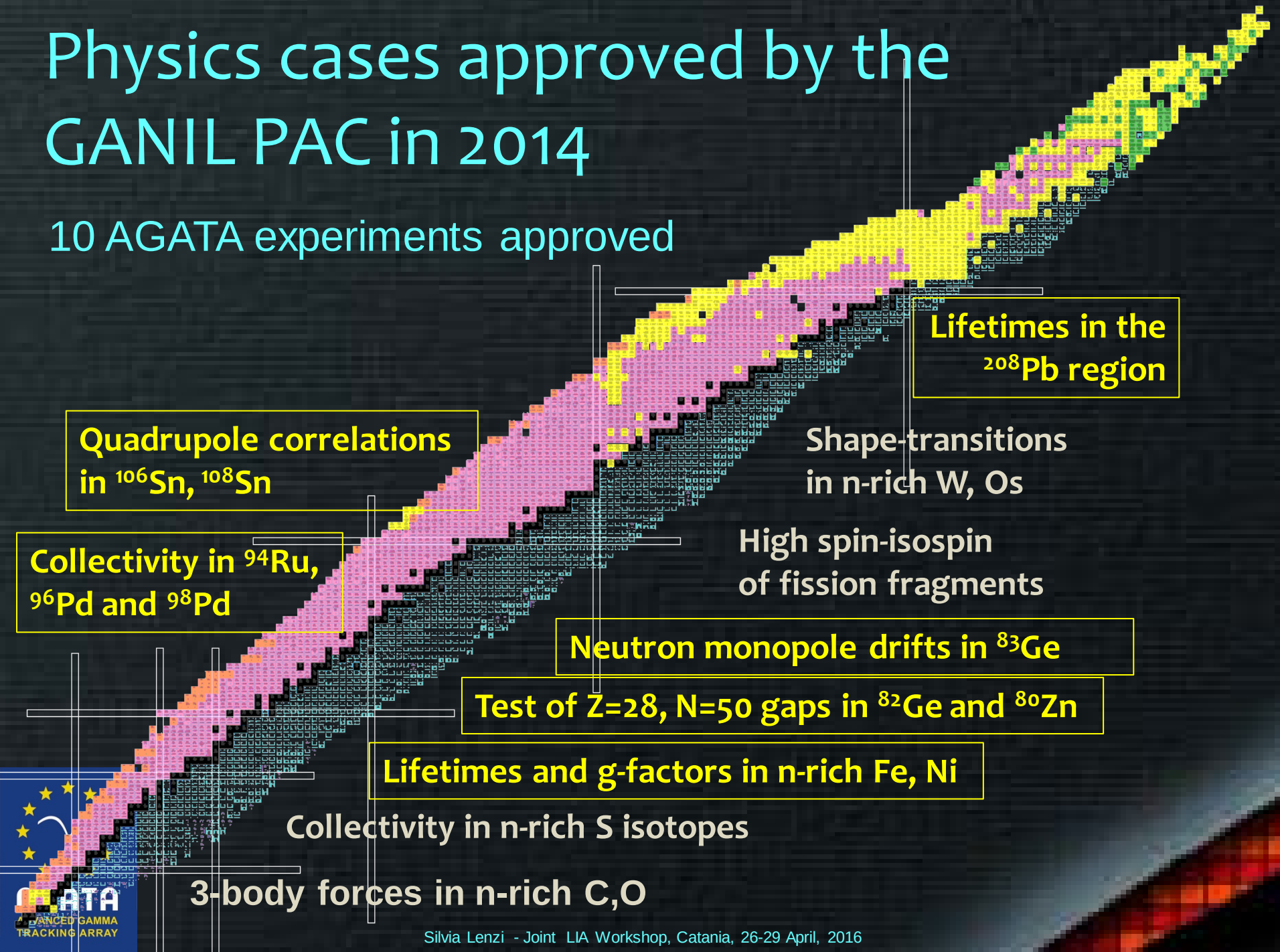
Physics cases approved by the GANIL PAC in 2014

10 AGATA experiments approved



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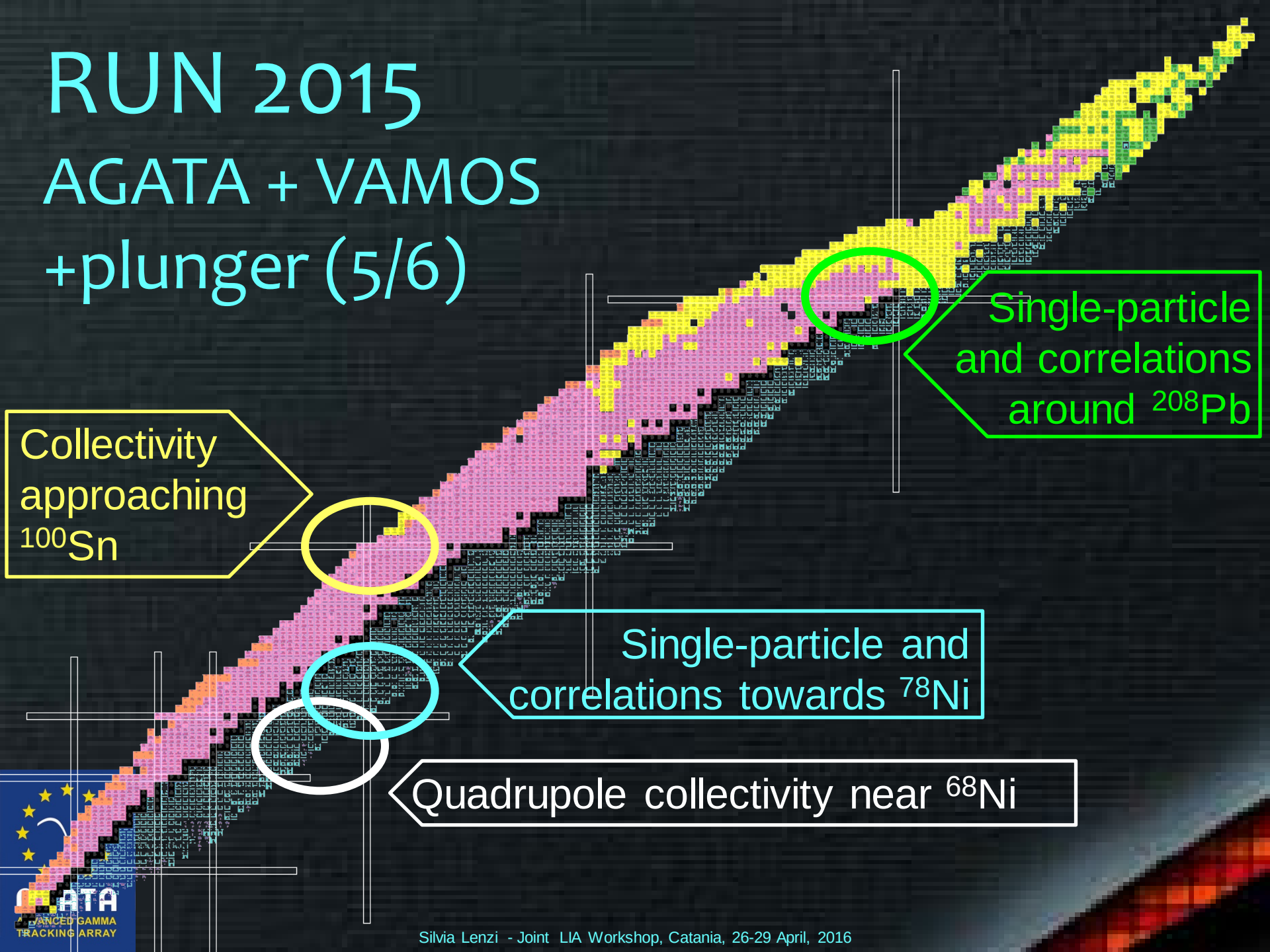
AGATA First Run: 8 clusters

RUN 2015

AGATA + VAMOS +plunger (5/6)



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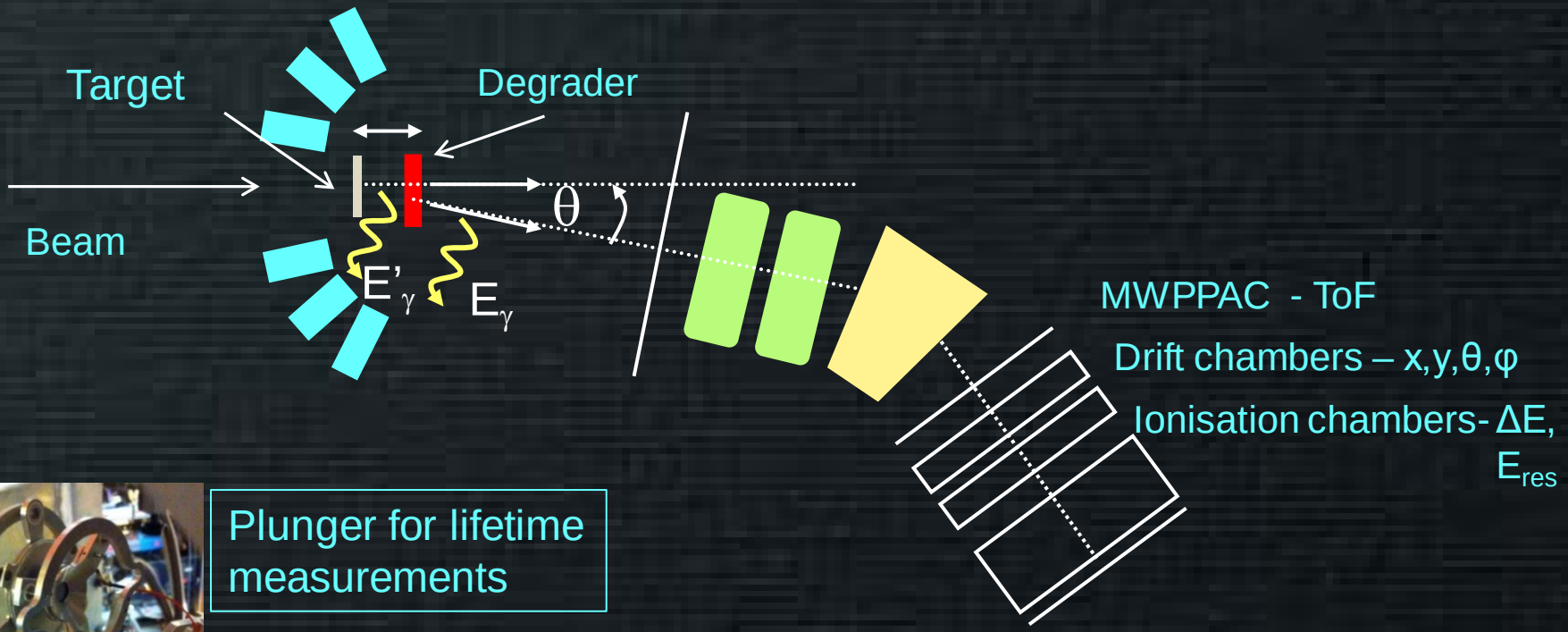
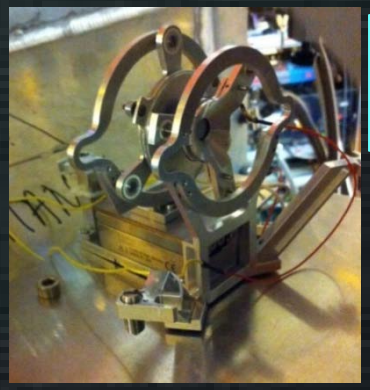
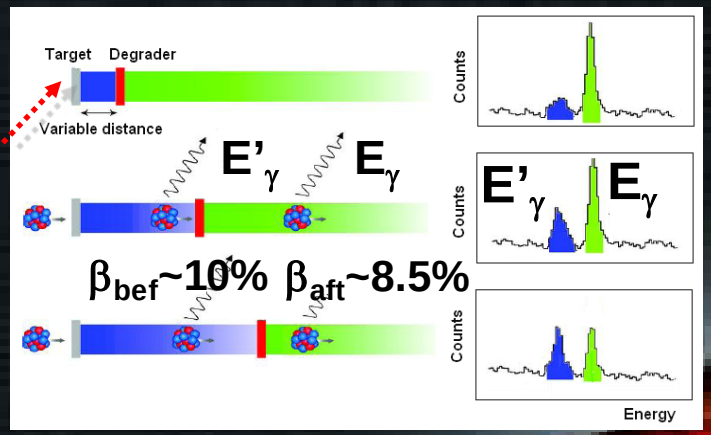
Experimental setup





Plunger for lifetime measurements



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

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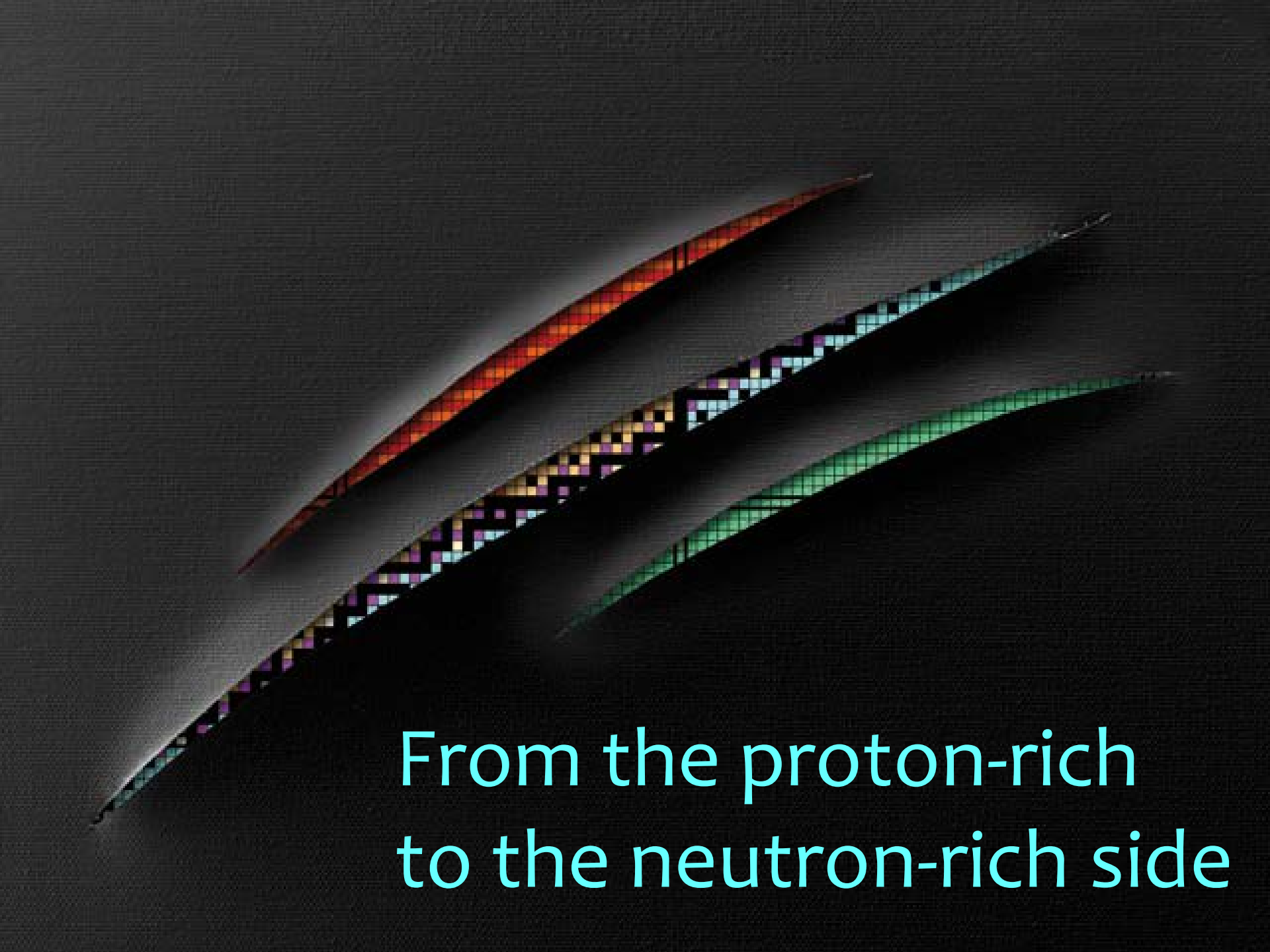
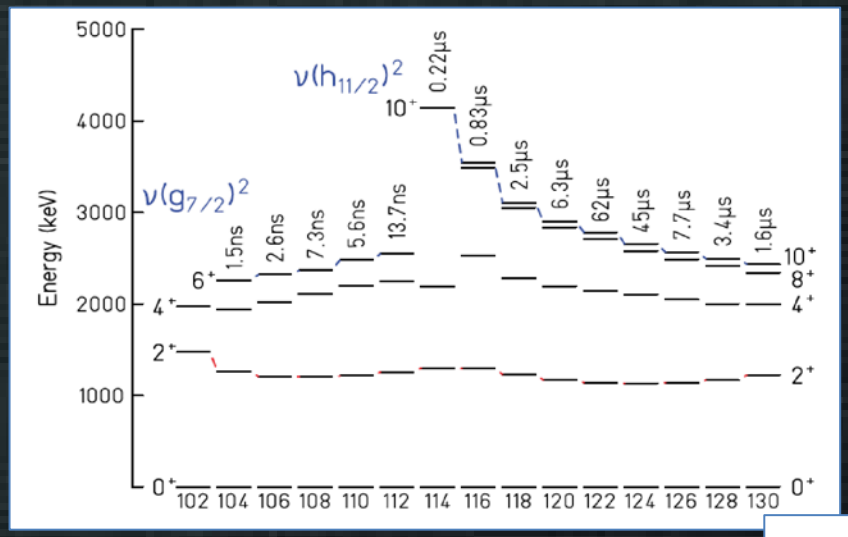

From the proton-rich
to the neutron-rich side

B(E2) determination in ^{106,108}Sn

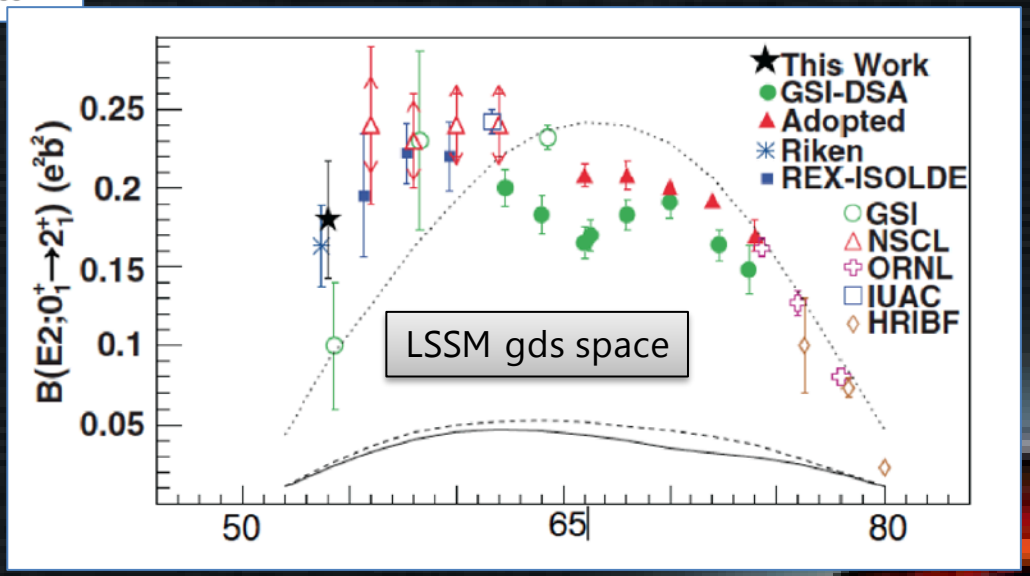
E664 J.J.Valiente-Dobon *et al*.



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

Several experiments performed, but large error bars.

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



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

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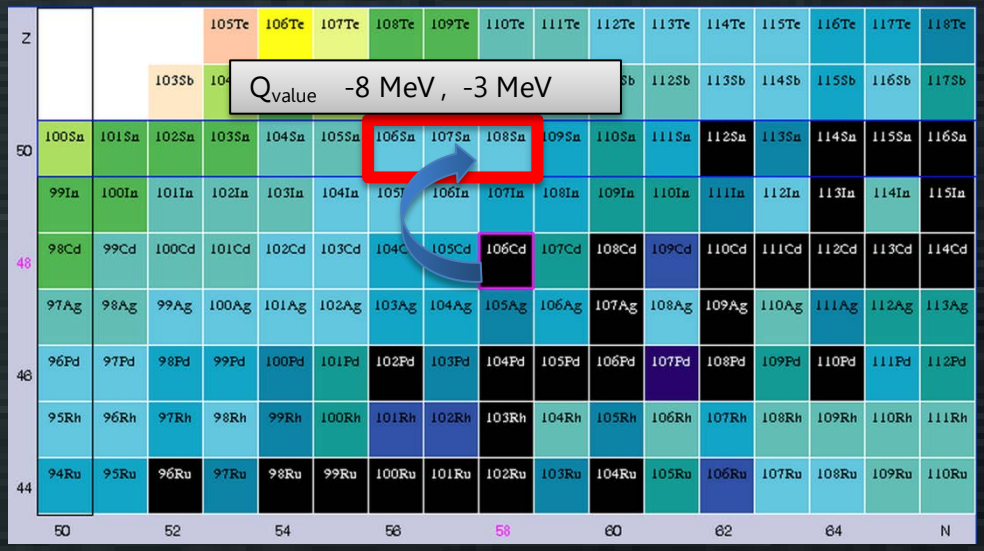
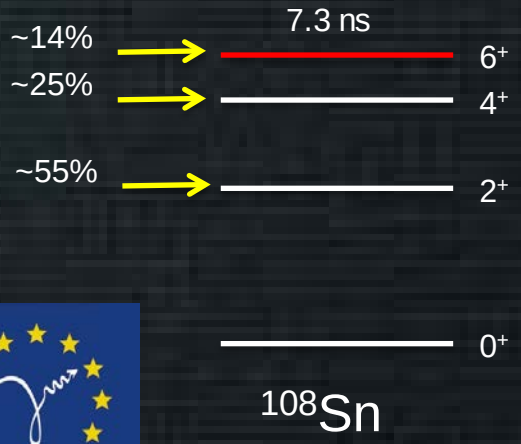
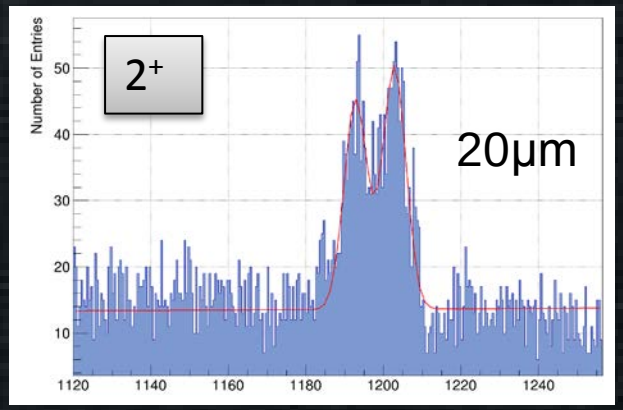
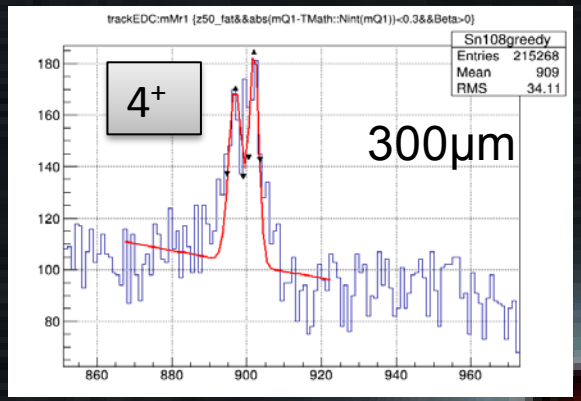
Online plunger spectra



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





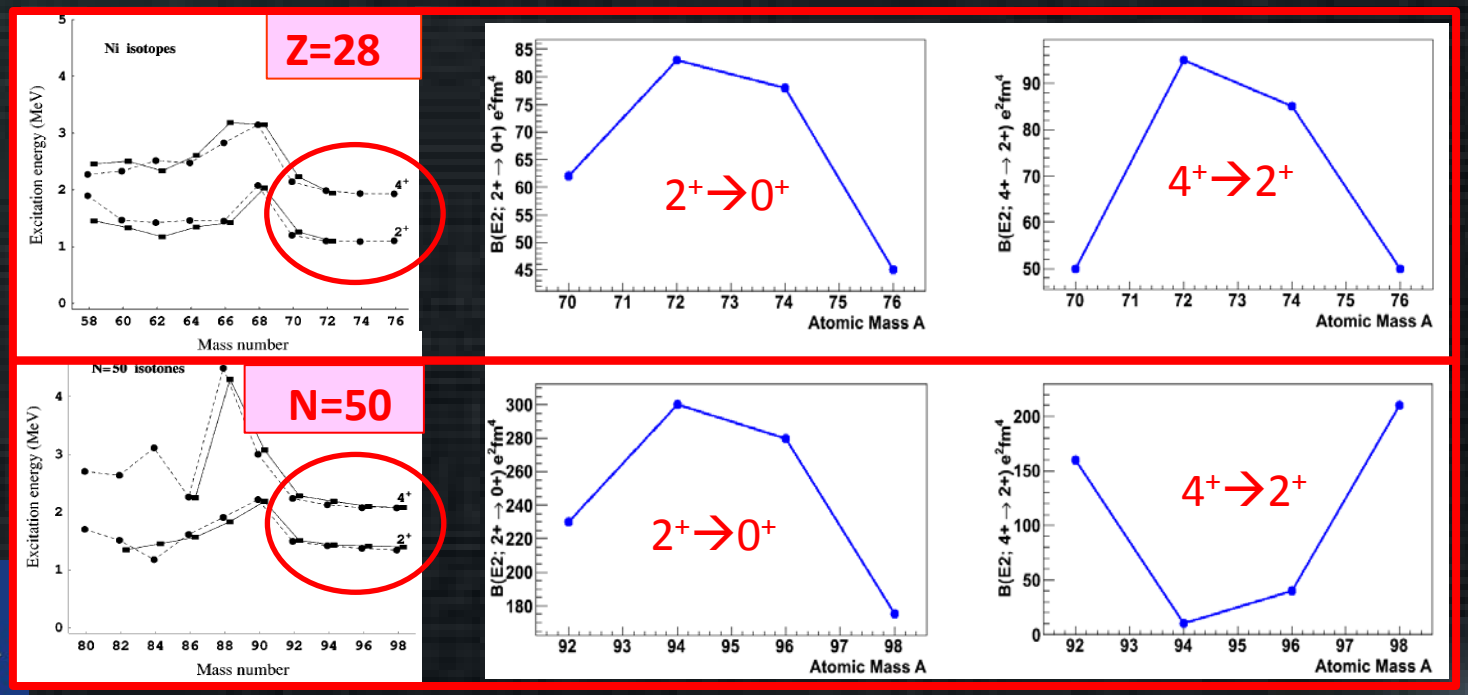


Courtesy M. Siciliano and J.J. Valiente-Dobon

Transition probabilities in the N=50 ^{92}Mo and ^{94}Ru

E682 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)

N=50

π $1g_{9/2}$

π $2p_{1/2}$

π $1f_{5/2}$

π $2p_{3/2}$

ν $2p_{3/2}$ ν $1f_{5/2}$ ν $2p_{1/2}$ ν $1g_{9/2}$

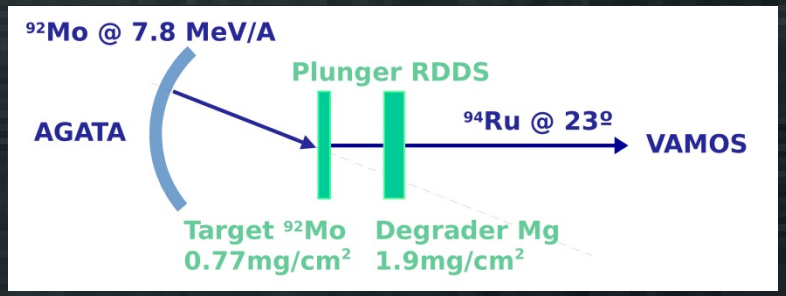
Z=28

AGATA ADVANCED GAMMA TRACKING ARRAY

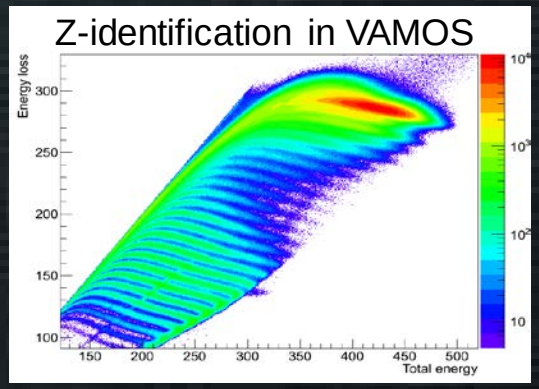
^{100}Sn ^{99}In ^{98}Cd ^{97}Ag ^{96}Pd ^{95}Rh ^{94}Ru ^{93}Tc ^{92}Mo ^{91}Nb ^{90}Zr ^{89}Y ^{88}Sr ^{87}Rb ^{86}Kr ^{85}Br ^{84}Se ^{83}As ^{82}Ge ^{81}Ga ^{80}Zn ^{79}Cu ^{78}Ni

^{56}Ni ^{57}Ni ^{58}Ni ^{59}Ni ^{60}Ni ^{61}Ni ^{62}Ni ^{63}Ni ^{64}Ni ^{65}Ni ^{66}Ni ^{67}Ni ^{68}Ni ^{69}Ni ^{70}Ni ^{71}Ni ^{72}Ni ^{73}Ni ^{74}Ni ^{75}Ni ^{76}Ni ^{77}Ni

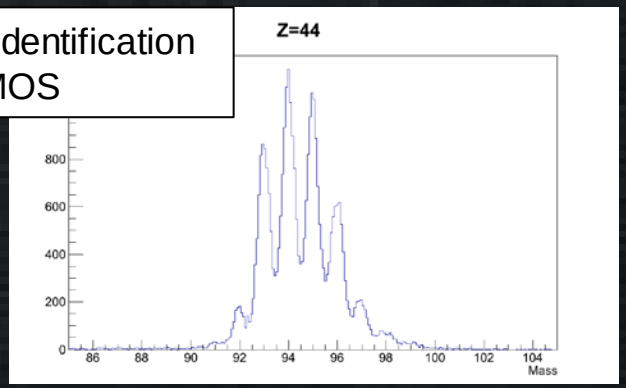
Preliminary results



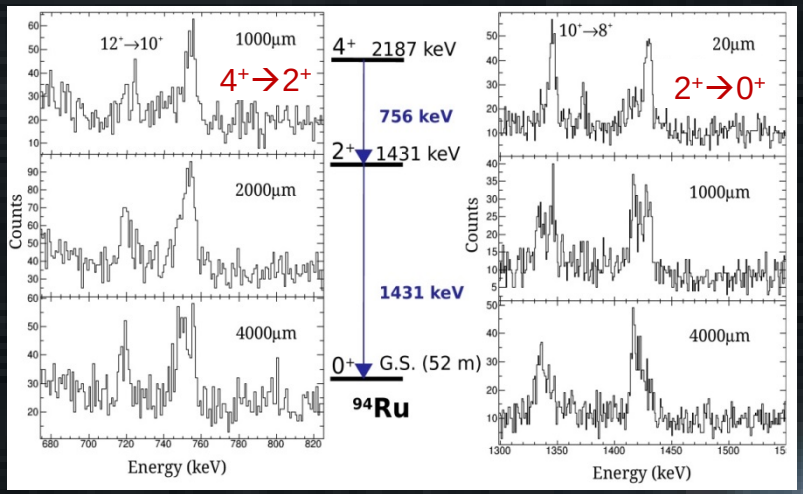
Lifetimes have been obtained for the $2^+ \rightarrow 0^+$ and $4^+ \rightarrow 2^+$ transitions in ^{92}Mo and ^{94}Ru



mass-identification in VAMOS



Online spectra for ^{94}Ru



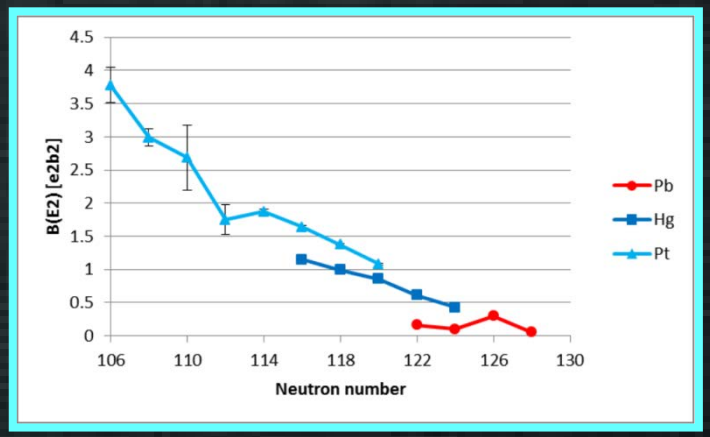
Analysis in progress!

Courtesy of R. Perez

Lifetimes in the ^{208}Pb region

E672 G. Georgiev *et al.*

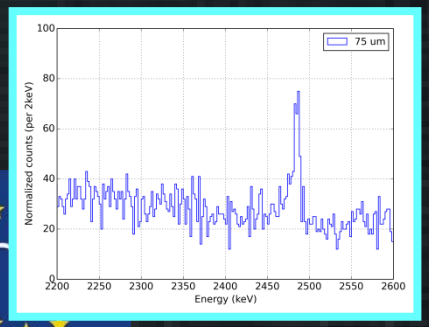
Motivation: information on transition probabilities and g-factors near the Z=82 and N=126 shell closures.

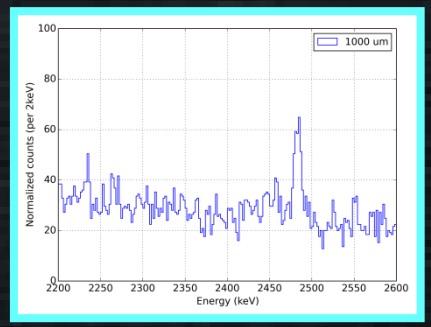


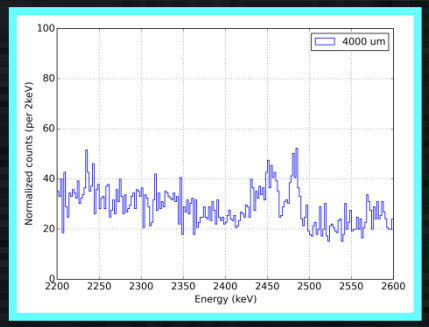
^{208}Pb beam at 6.25 Mev/u on ^{100}Mo target

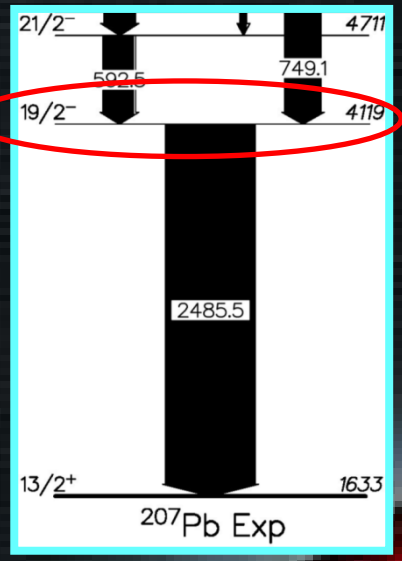
Populated in multi-nucleon transfer reactions.
VAMOS + PLUNGER

Preliminary results: Lifetime of high-spin states in ^{207}Pb





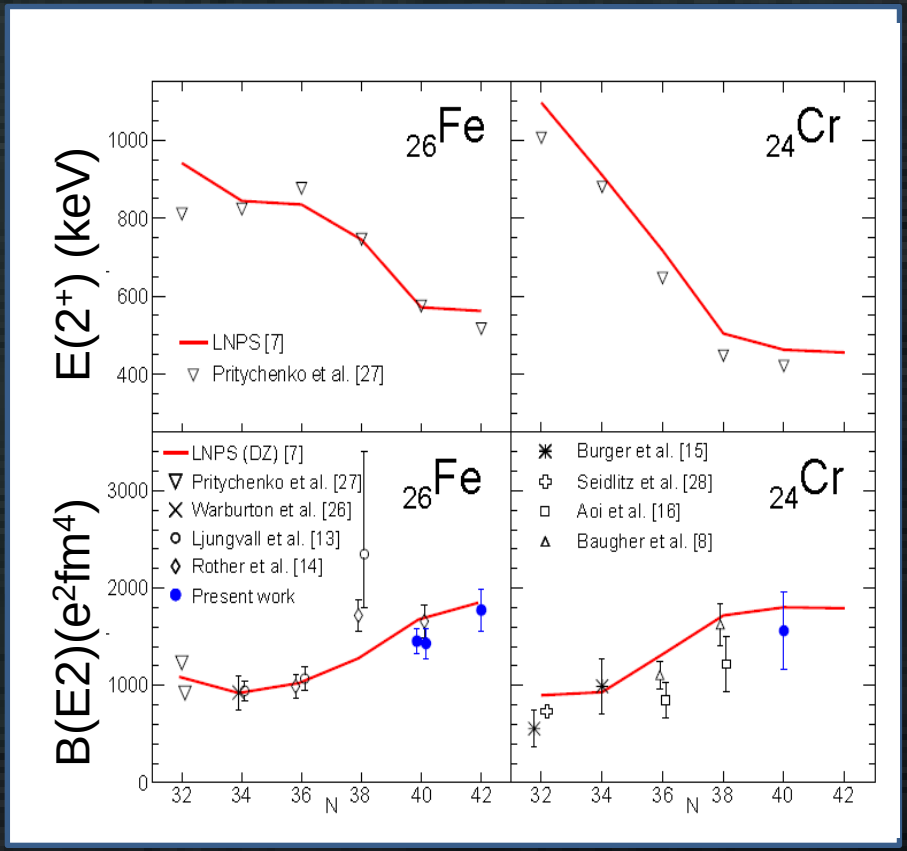




Courtesy of D. Ralet

Lifetimes near N=40

E663 J. Ljungvall *et al.*



H. L. Crawford et al., PRL 110, 242701 (2013)

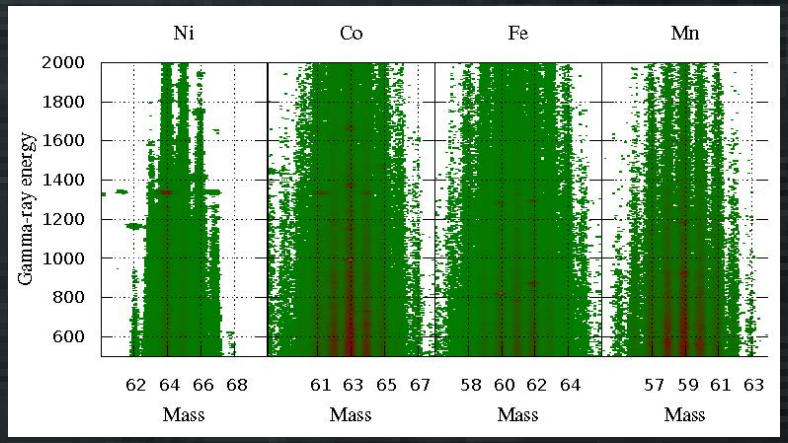
Motivation: understanding the development and the trend of deformation in the third island of inversion.

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

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

Comparison with LSSM calculations in the fpgd model space

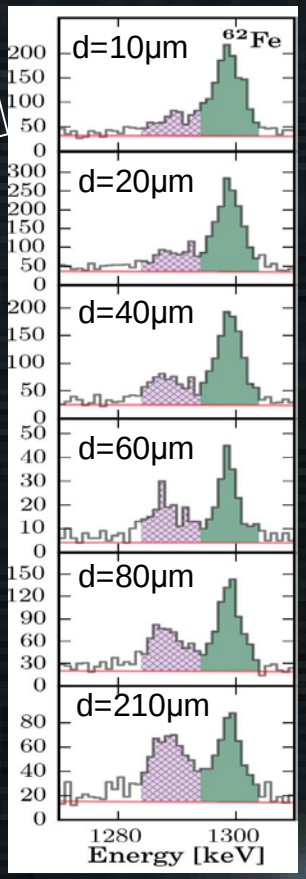
Preliminary results

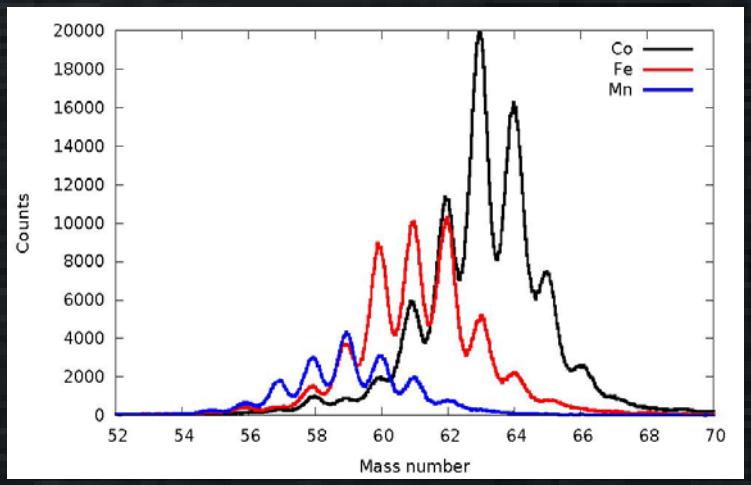


Several new lifetimes in the four isotopic chains

Gamma spectra at different distances

^{62}Fe 4^+ state





Publication in preparation

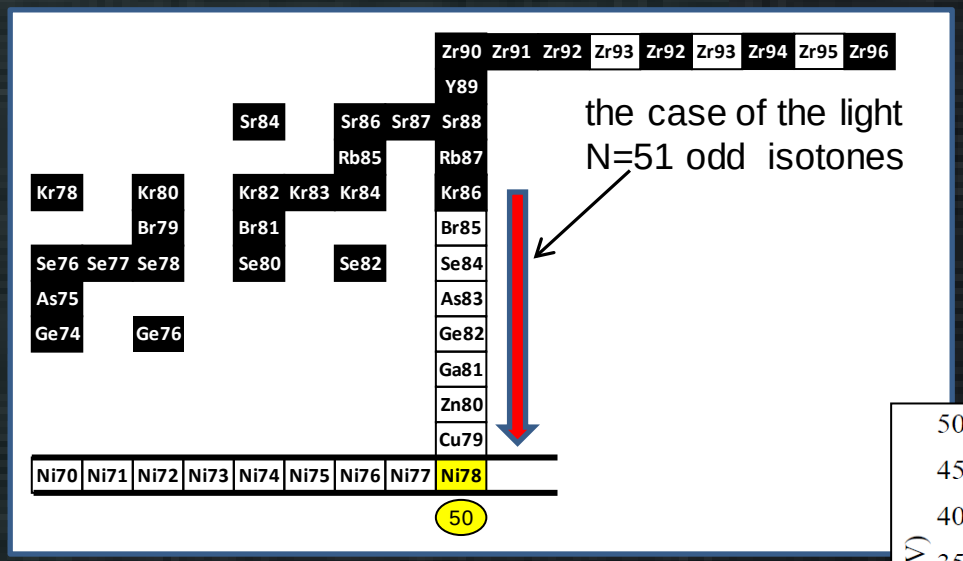
Courtesy of Joa Ljungvall

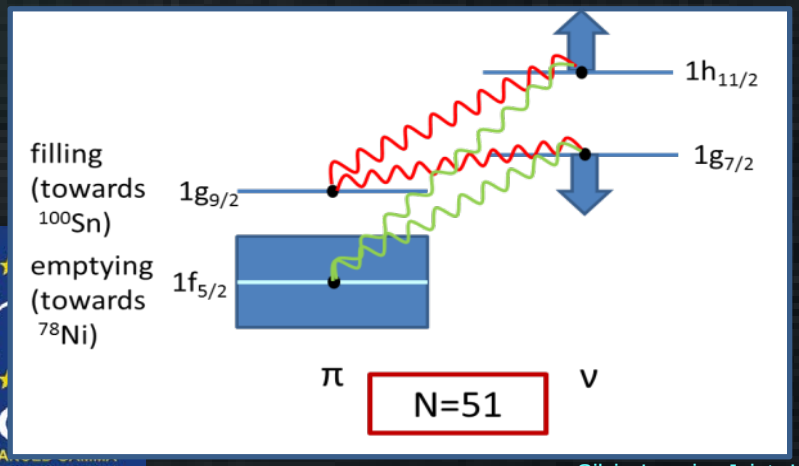
AGATA
ADVANCED GAMMA TRACKING ARRAY

Neutron structure above ^{78}Ni

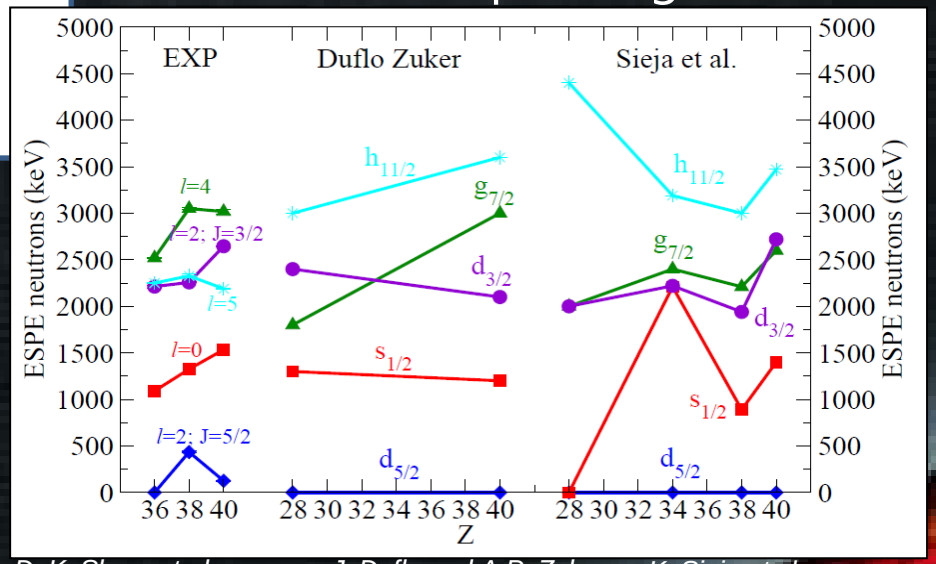
E669 Verney *et al.*

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





Effective s.p. energies

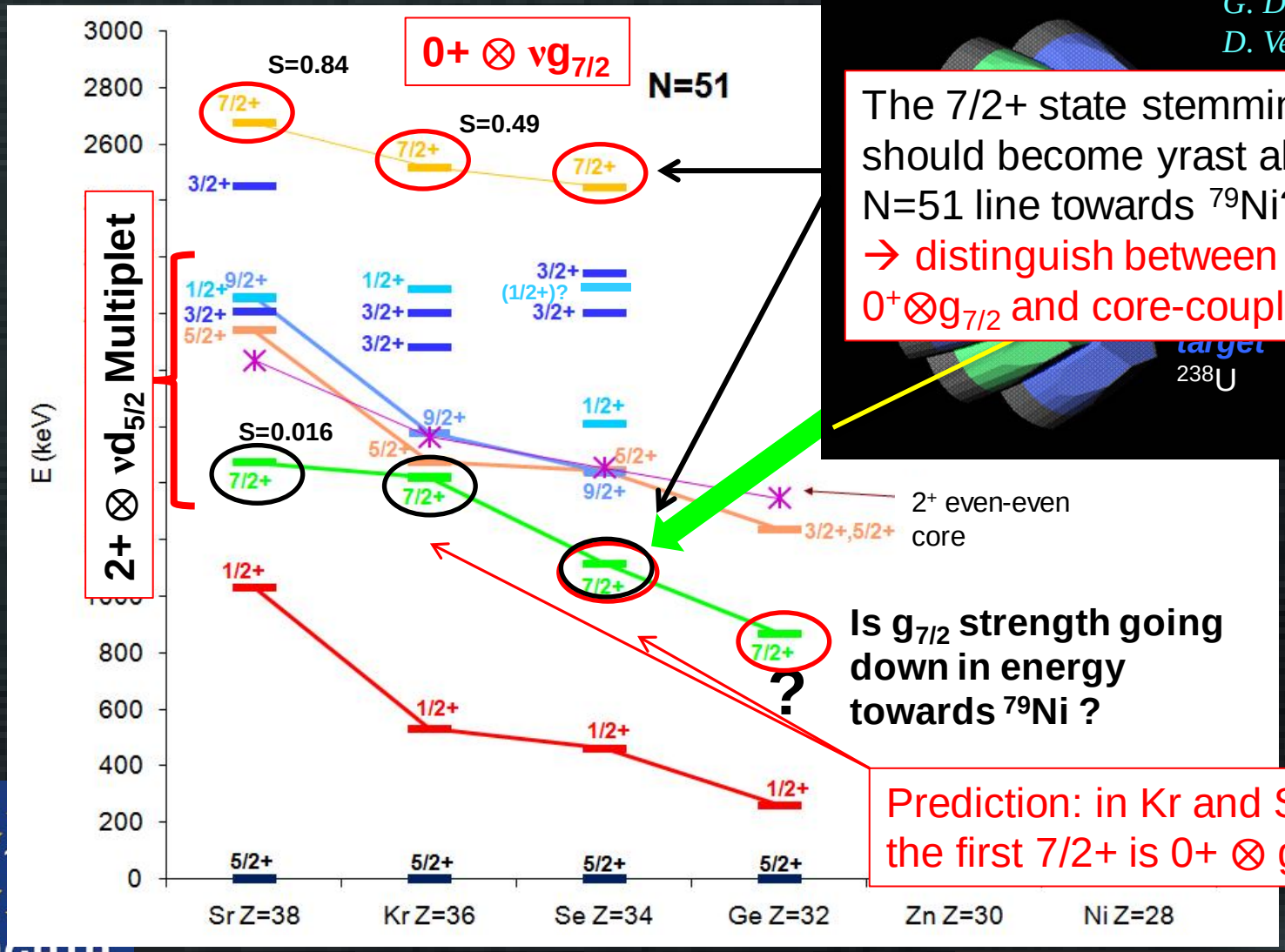


*D. K. Sharp et al., PRC **87**, 014312 (2013)*

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

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

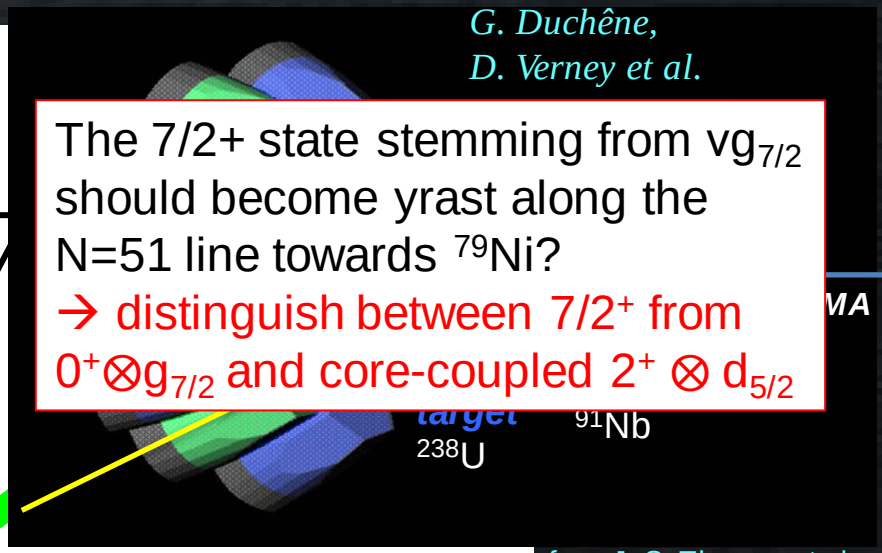
Nature of the 7/2⁺ states



F. Didierjean, G. Duchêne, D. Verney et al.

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

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



from J. S. Thomas et al. PRC 76, 044302 (2007)

Prediction: in Kr and Se the first 7/2+ is $0+ \otimes g_{7/2}$

Courtesy of F. Didierjean and A. Gottardo

Lifetime measurements in N=51

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

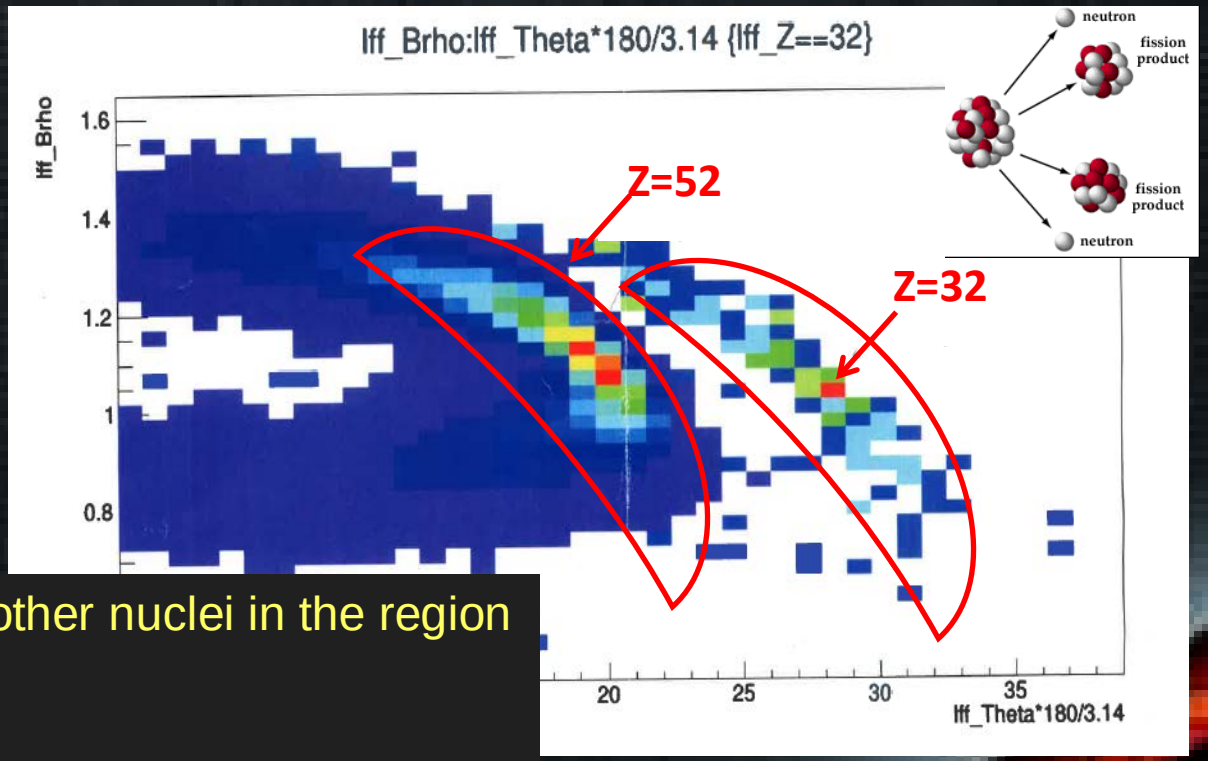
$[2^+ \otimes d_{5/2}]\ 7/2_1$	short lived	**2 orders of magnitude difference**
$[0^+ \otimes g_{7/2}]\ 7/2_1$	long lived	

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

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

M. Caamaño et al., PRC 88, 024605 (2013) and erratum

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

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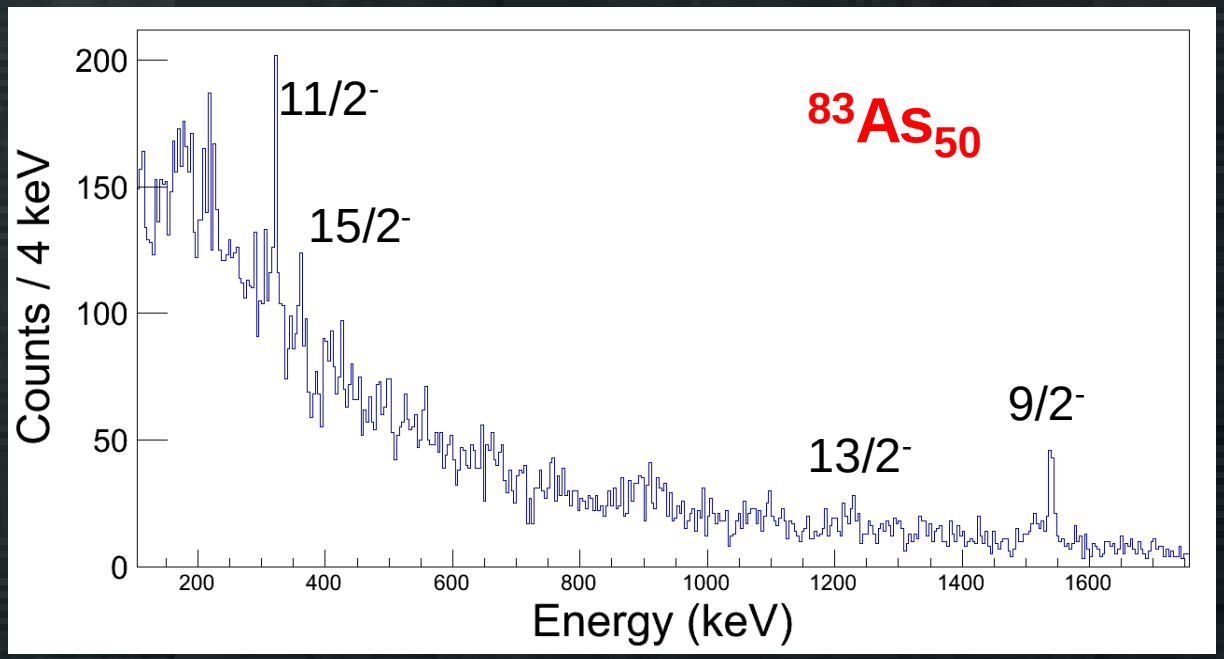
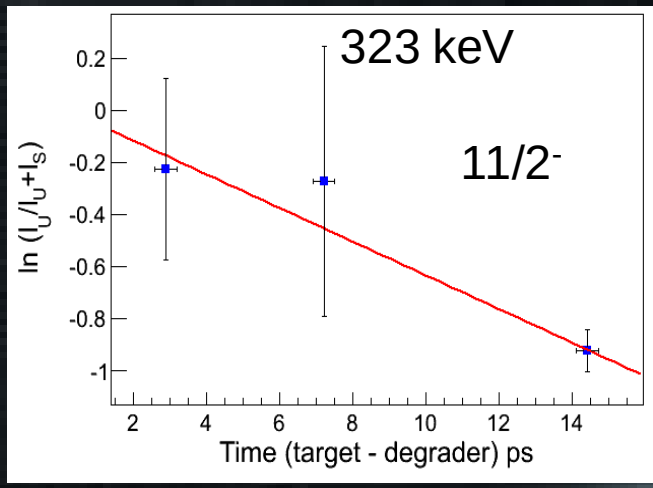
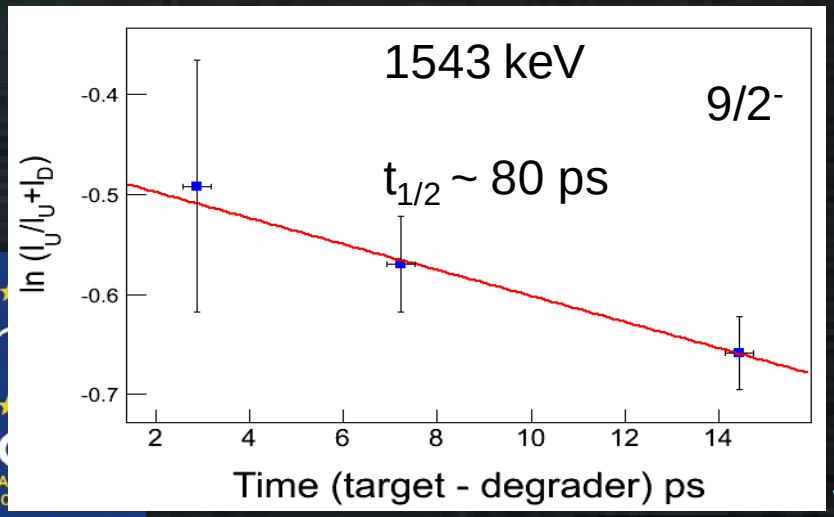
Preliminary results



Gamma spectrum at 100μm distance:
Improving Doppler correction
Cleaning background





The **premilinary** lifetime anlysis shows long-living low-lying states.

Courtesy of A. Gottardo

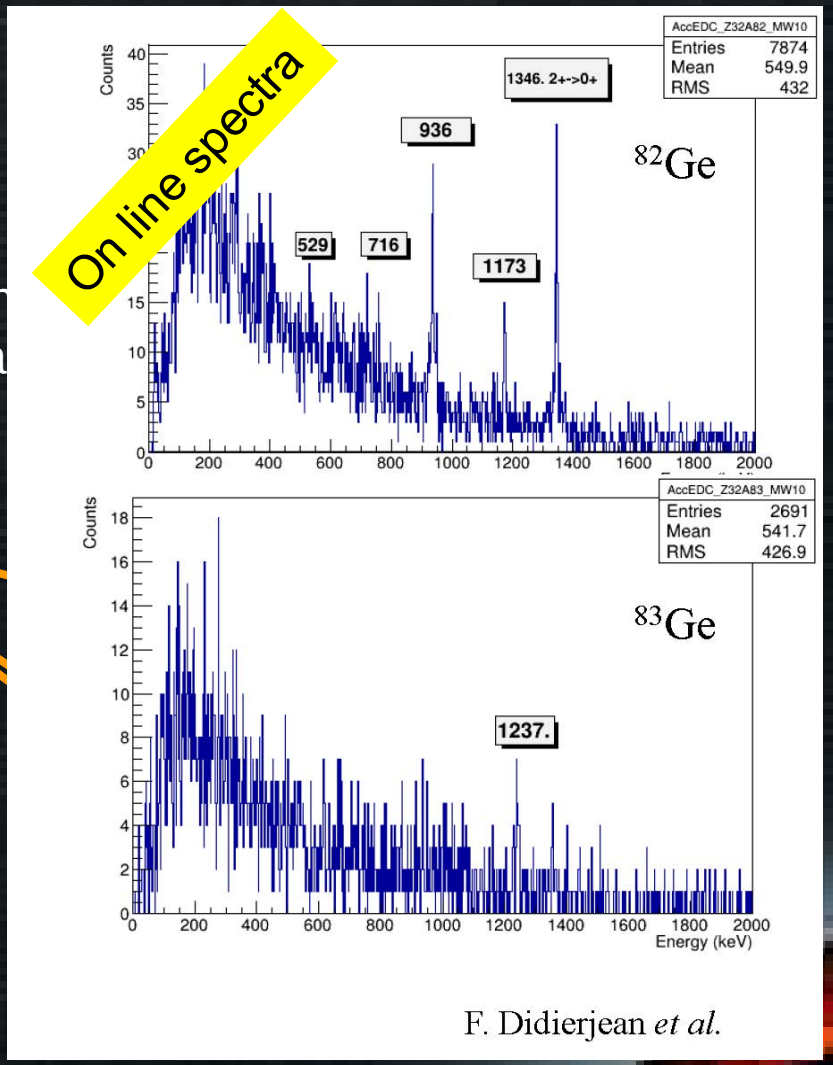
Test of Z=28, N=50 gaps in ^{80}Zn and ^{82}Ge

E680 G. Duchene, G. de Angelis *et al*.

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

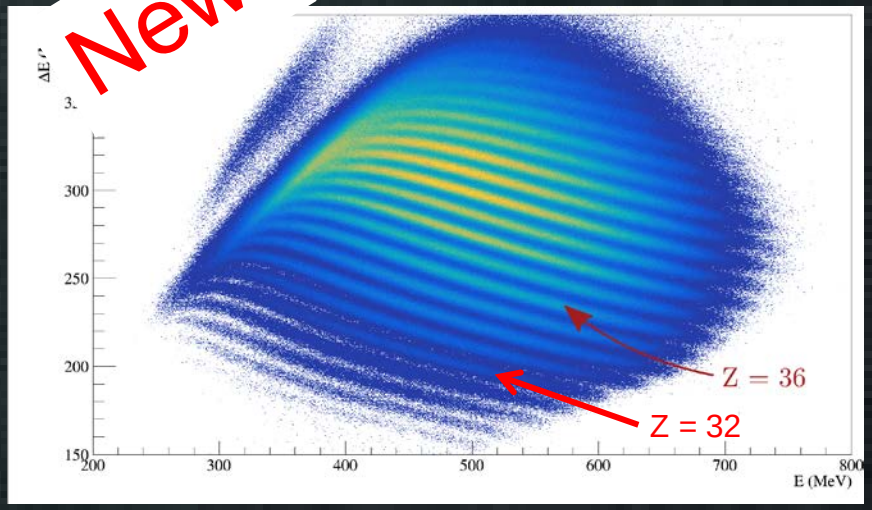
LSSM calculations predict an increase of excitation energy towards ^{78}Ni

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



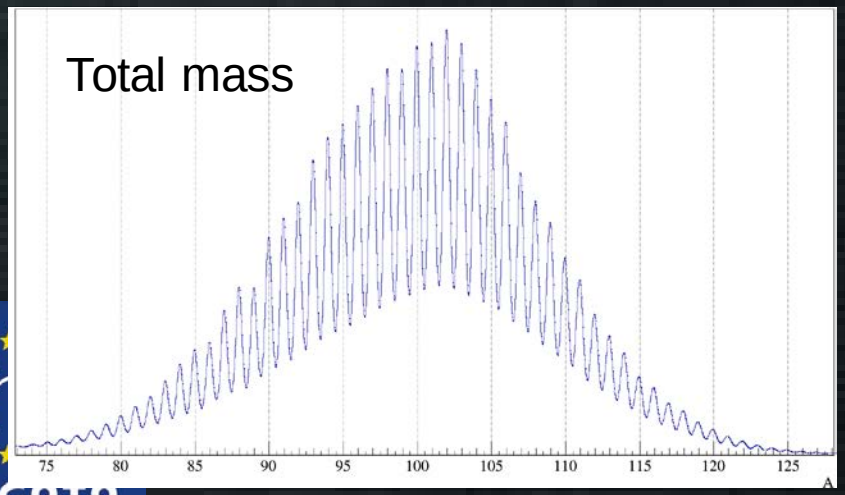
VAMOS Analysis

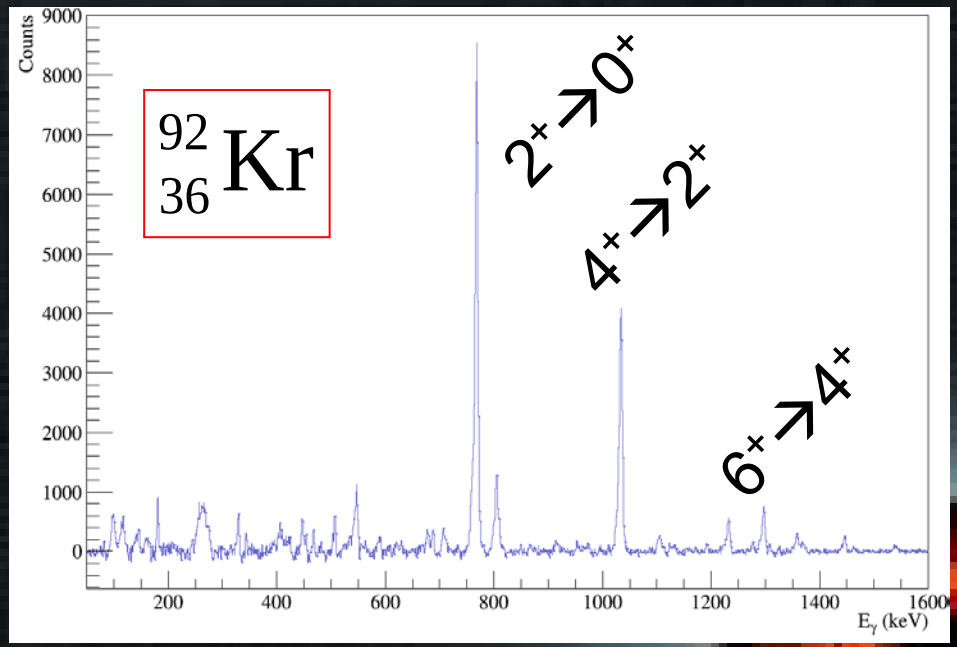
New!



The analysis of the VAMOS part is finished.
Gamma-ray analysis in progress

Example: ^{92}Kr
(Z=36, N=56, N/Z ~ 1.56)





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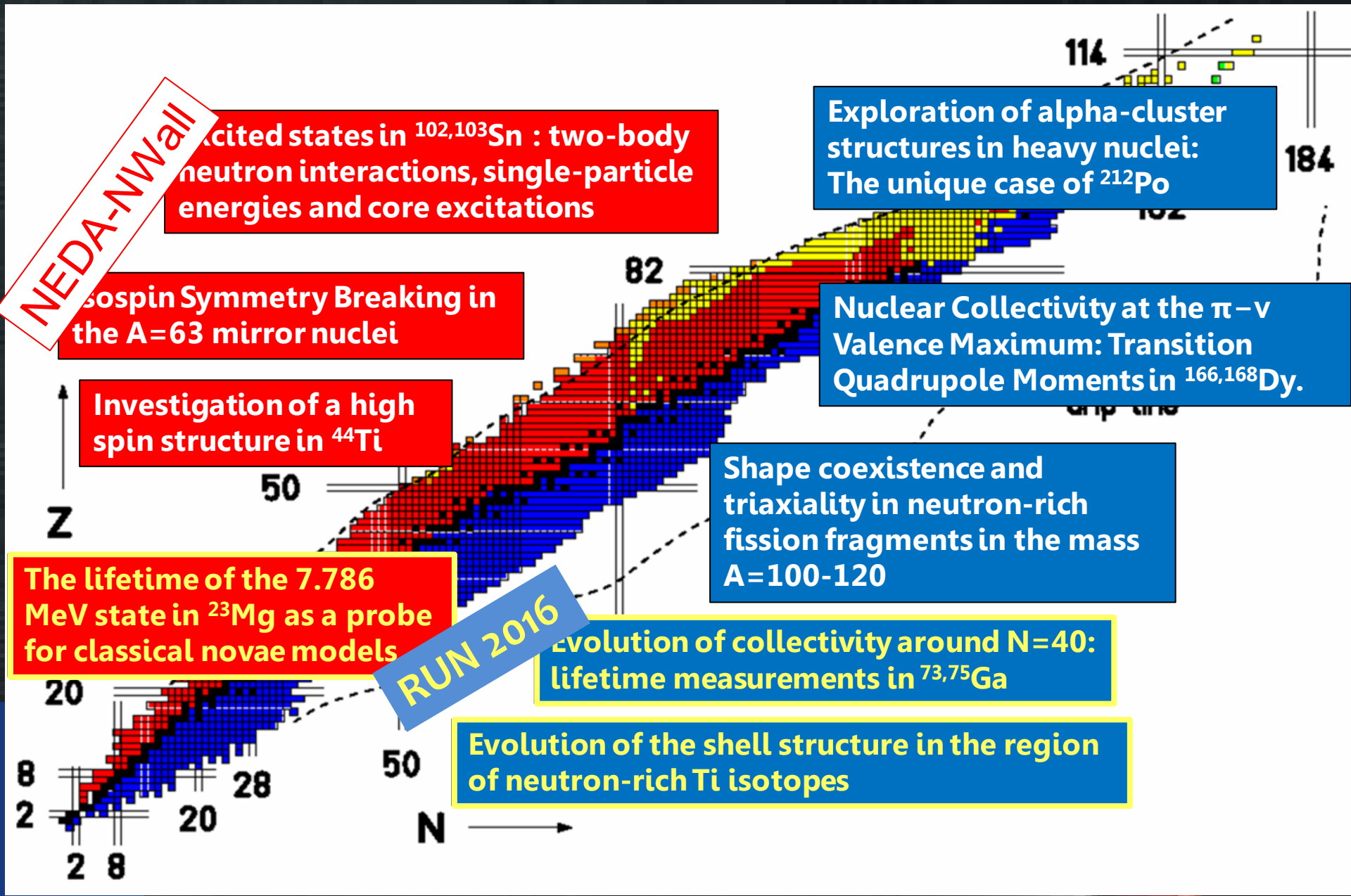
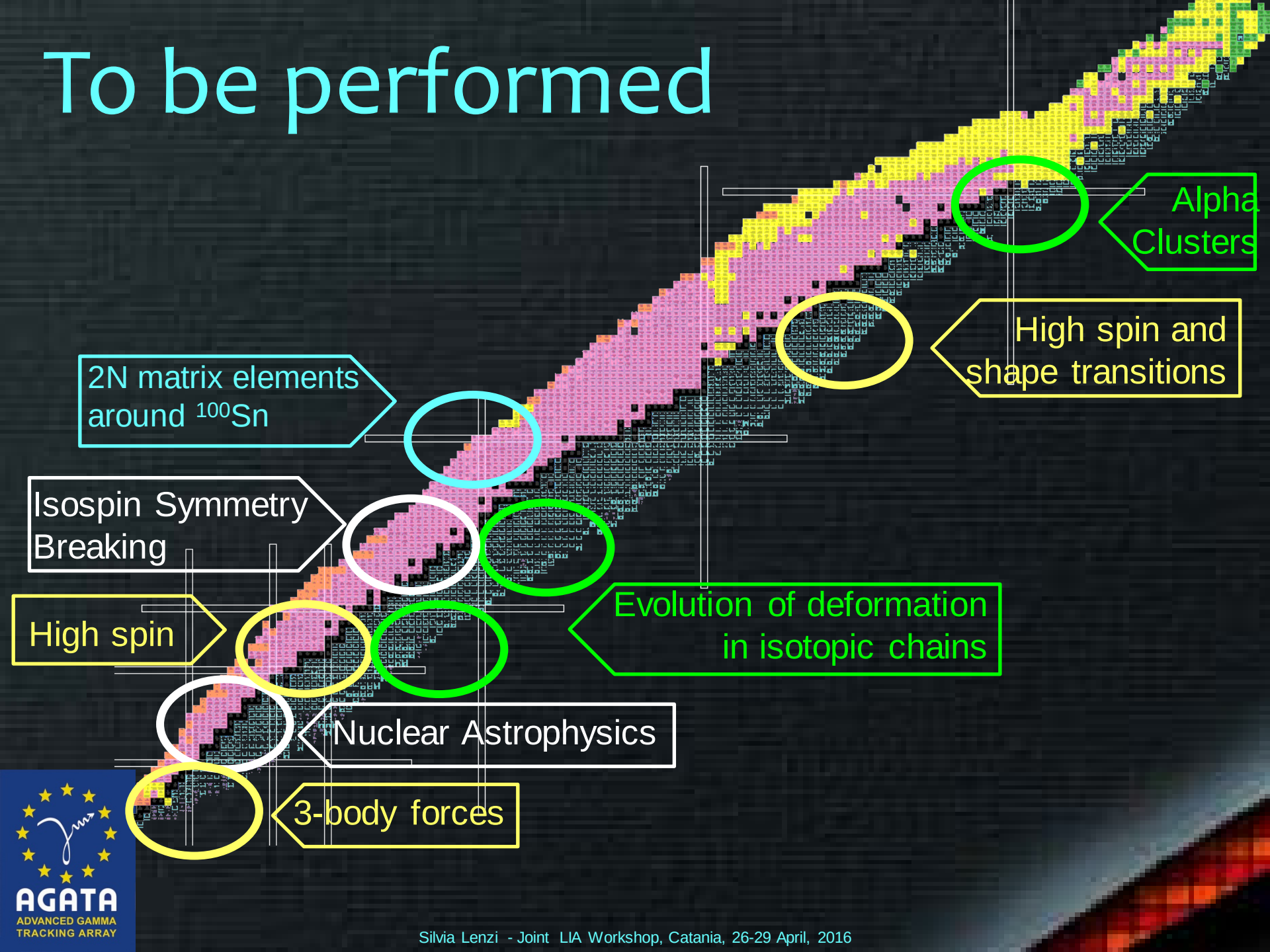
Courtesy of J. Dudouet

Experiments approved in 2015



To be performed



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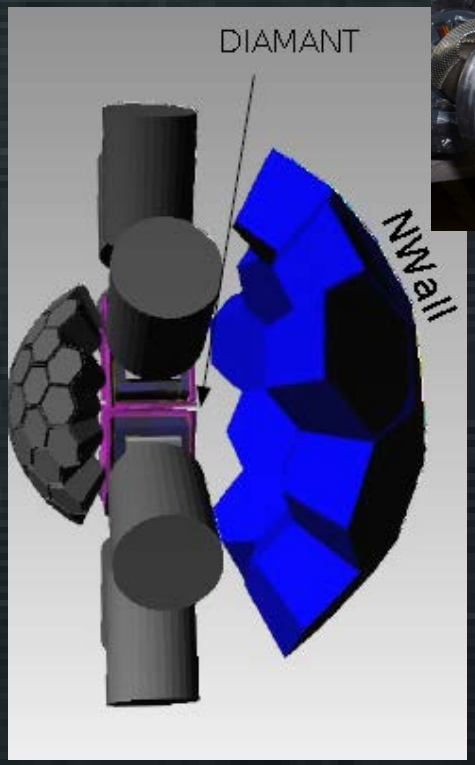
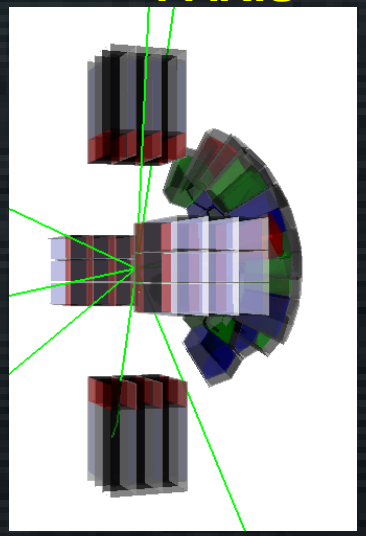
Future setups include

NEDA

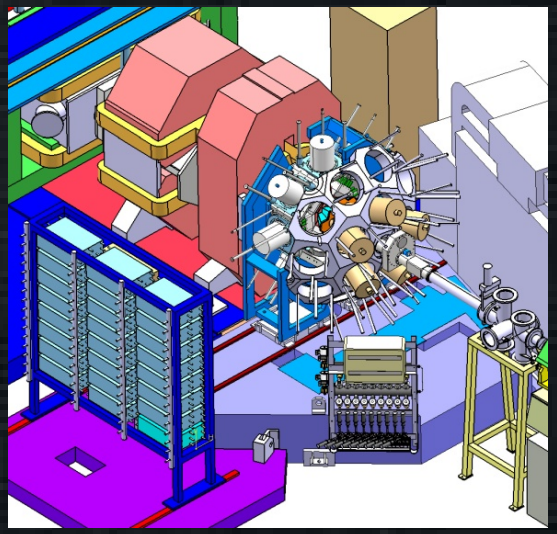


DIAMANT

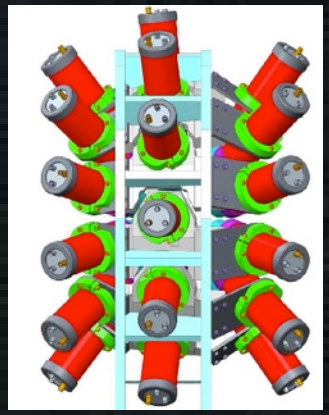
PARIS



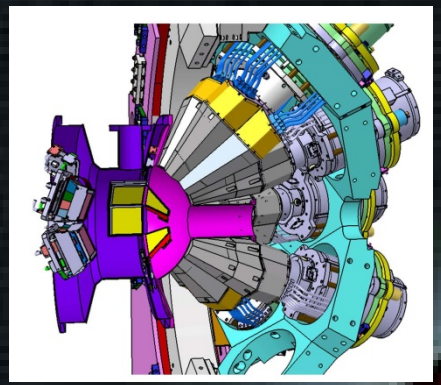
VAMOS gas-filled mode



FATIMA

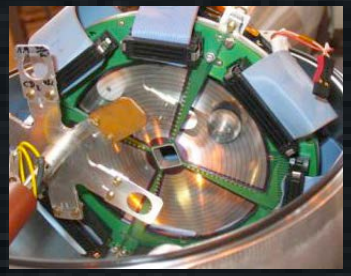


MUGAST



plunger

DSSSD



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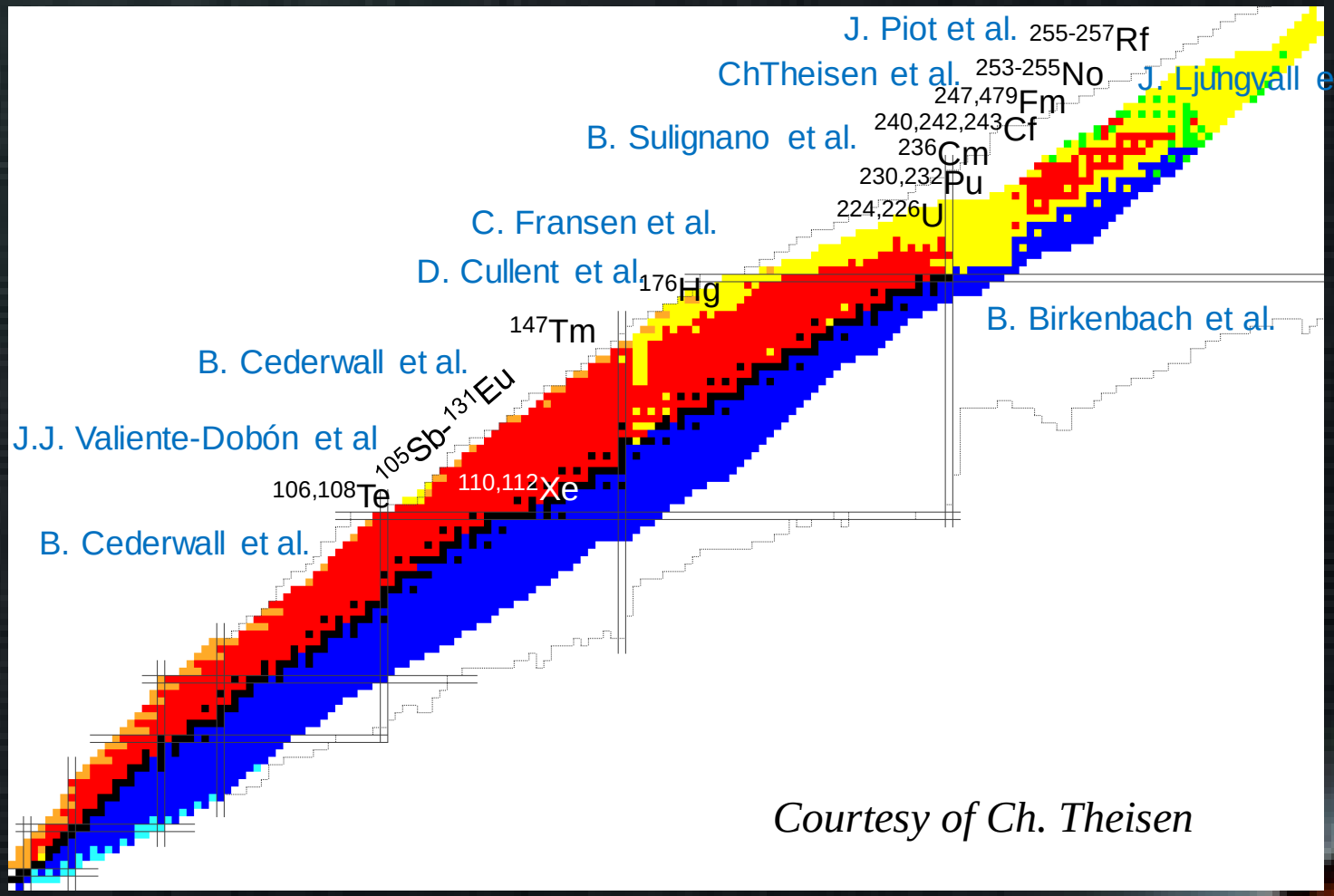
LoI for a campaign of AGATA coupled to VAMOS in gas-filled mode



LoI for a campaign of AGATA coupled to MUGAST

MUGAST Workshop 2016

Nuclear astrophysics

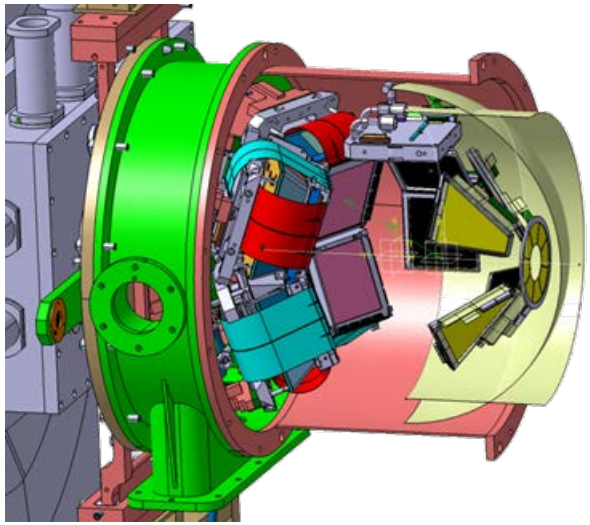
- $^{15}O(^{6}Li,d)^{19}Ne$ *(C.Diget, N. de Séréville)*
- $^{25}Al(^{3}He,d)$ *(N.de Séréville, F. Hammache)*
- $^{30}P(^{3}He,d)$ or (d,p) *(N.de Séréville, F.Hammache)*
- $^{60}Fe(d,p)$ *(A.Matta, W.Catford)*
- $^{79}Se(d,p)^{80}Se$ *(G. de Angelis, D.Mengoni, C.Domingo Pardo)*

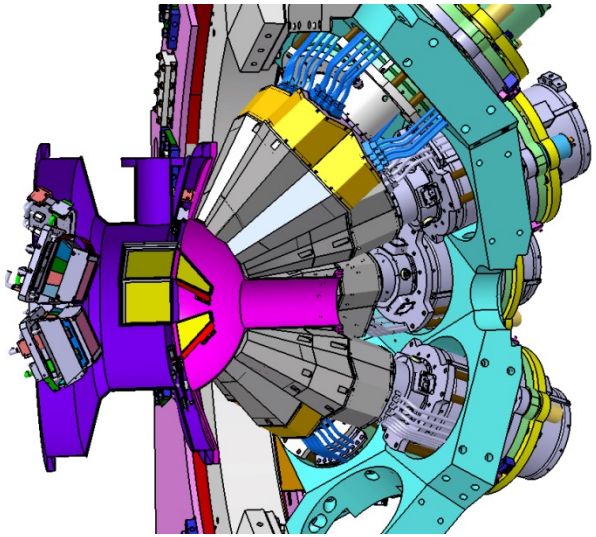
Shell evolution

- $^{56}Ni(d,p)(d,t)$ *(F.Flavigny, O.Sorlin)*
- $^{28}Mg(d,p)$ *(A.Matta, W.Carford)*
- $^{74}Kr(d,p)$ *(A.Matta, W.Carford)*
- $^{48}Cr(d,p)^{49}Cr$ *(A.Gadea)*
- $^{30}Mg(d,d)(d,p)$ *(B.Fernandez-Dominguez)*
- $^{67}As,^{63}Ga(^{3}He,d)$ *(D.Mengoni)*
- $^{44,46}Ar(t,p)$ *(D.Mengoni)*
- $^{66}Ni(t,p),^{44}Ar(t,p)$ $(^{14}C,^{12}C)(^{18}O,^{16}O)$ *(L.Fortunato, J.A.Lay)*

Clusters, pairing, correlations & others

- $^{56}Ni(^{3}He,p)(^{6}Li,\alpha)$ *(M.Assie)*
- $^{45}K + ^{7}Li \rightarrow ^{46}Ca+\alpha$ *(S.Leoni, B.Fornal)*
- $^{16}O + ^{A}Z$ *(G.Verde)*
- $^{14}O(p,p)$ *(I.Stefan)*

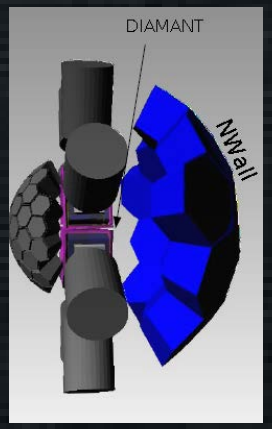




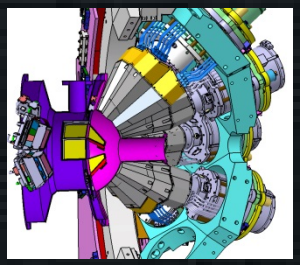
Courtesy of M. Assié

AGATA Campaign Timeline

2016-2017: Run experiments with VAMOS in vacuum mode and other ancillary detectors such as plunger, FATIMA, PARIS, DSSSD.

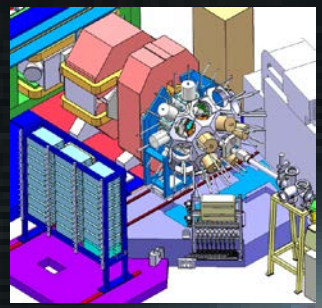


2018: Run experiments with NEDA + Neutron-wall + DIAMANT and other ancillaries such as plunger, FATIMA, PARIS, DSSSD.



2019: SPIRAL1 beams and MUGAST

VAMOS in gas-filled mode



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NUSPIN 2016 Workshop

Nuclear Spectroscopy Instrumentation Network

and

AGATA Physics Workshop

Associated Events

- Kick-off Meetings of the NUSPIN Scientific Committee and Working Groups
- Annual Meeting of the AGATA Collaboration Council

Organizing Committee

S. M. Lenzi (chair, Padova), A. Boston (Liverpool), A. Gadea (Valencia), M. Górska (Darmstadt), A. Lopez-Martens (Orsay), S. Lunardi (Padova), D. Mengoni (Padova), D. R. Napoli (Legnaro), J. Nyberg (Uppsala), F. Recchia (Padova), J. J. Valiente Dobón (Legnaro)

Secretariat

Elena Pavan (INFN, Padova)
Adriana Schiavon (Università di Padova)

Info: http://nuspin.pd.infn.it/nuspin2016

San Servolo, Venice, 27 June - 1 July, 2016


Thank you
for your attention