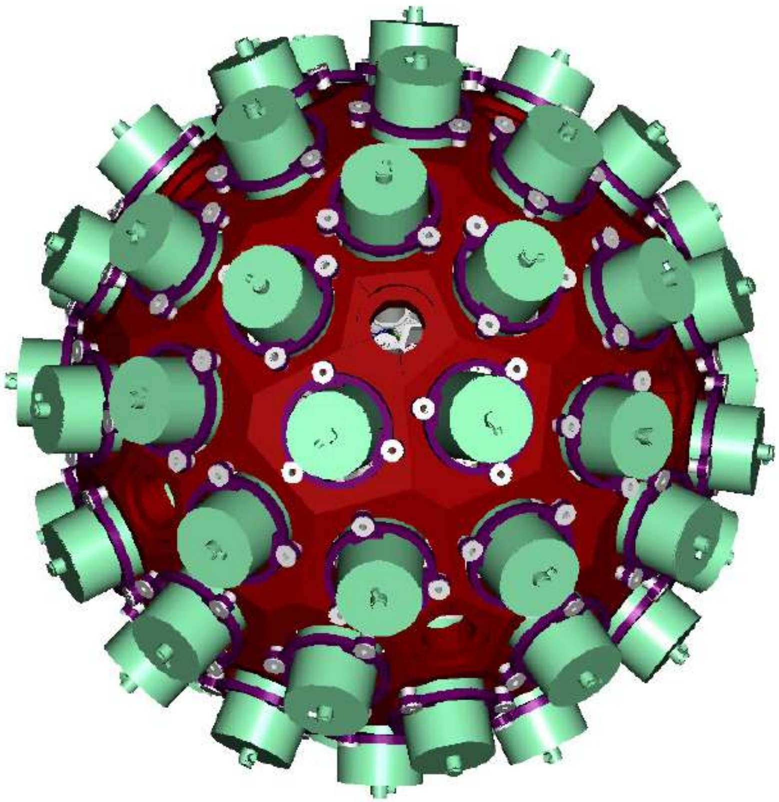
AGATA IS COMING BACK TO LEGNARO

Magda Zielińska, IRFU/DPhN, CEA Saclay

Nuclear Physics Seminar, Faculty of Physics, University of Warsaw, March 17, 2022

AGATA PROJECT



180 segmented crystals (60 triple units)

362 kg of Ge

82% solid angle

counting rate: 50 kHz per Ge crystal

angular resolution: ~1°

efficiency: 35% (M_γ=1), 20% (M_γ=30)
Peak/Total: ~40-50%

large inner radius to accommodate ancillary devices

http://www.agata.org
S. Akkoyun *et al.*, Nucl. Instrum. Methods Phys. Res. A 668, 26 (2012).

TRACKING ARRAYS

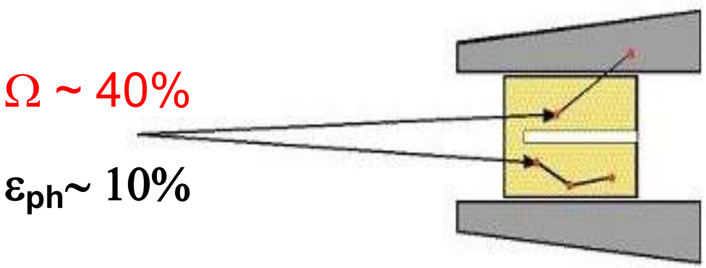
designed to maximize efficiency and peak-to-total ratio of high-resolution γ-ray detector arrays

1. Maximizing the active solid angle without compromising signal/noise ratio

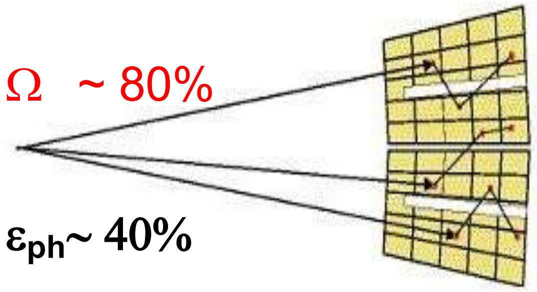
2. Improving the energy resolution in all experimental conditions, even at high emission velocities

3. Maximizing the detector performance, even in conditions of heavy duty with radiation damage

Compton suppressed



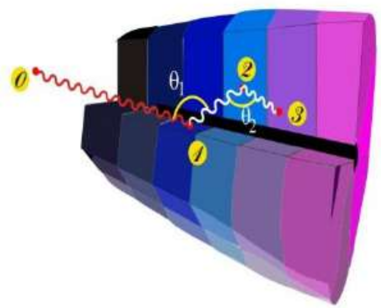
Tracking array



- Large solid angle
- Position sensitivity using PSA
- Large P/T using tracking for γ-ray reconstruction

TRACKING INGREDIENTS

1



2

100 Mhz, 14 bit sampling of segment and central contact signals

3

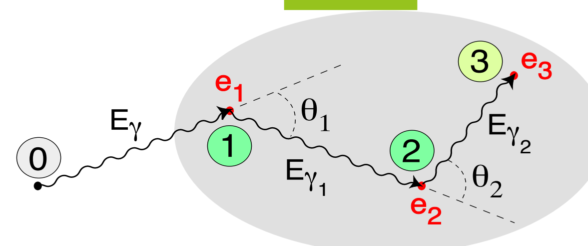
Pulse-Shape Analysis to decompose recorded waves

Identified interaction points

(x,y,z,E,t)

4

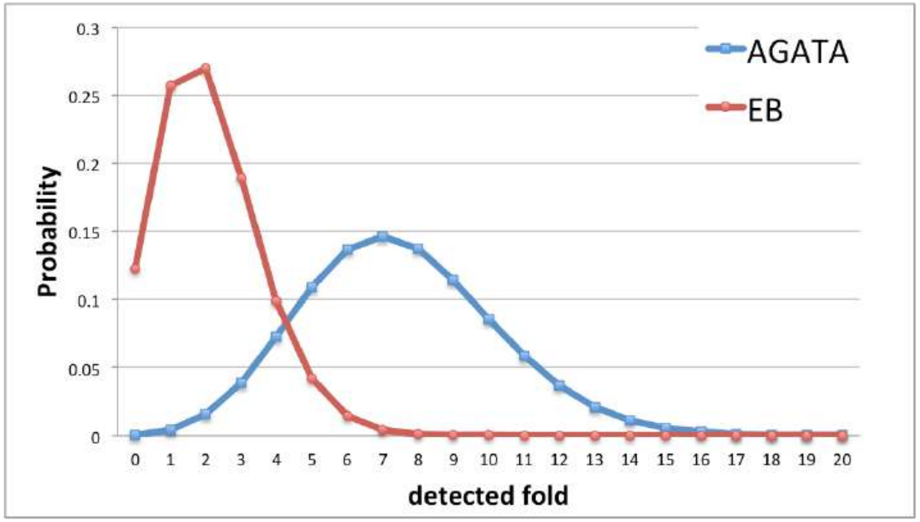
Reconstruction of photon trajectories by tracking algorithms



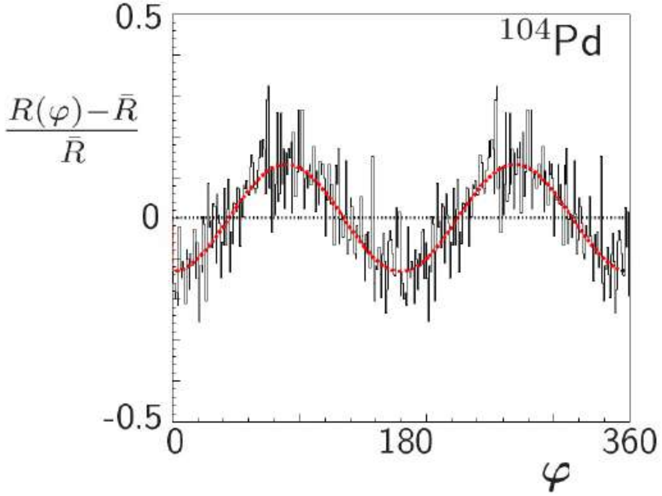
reconstructed γ-ray energies, emission and scattering directions

STRENGTHS OF AGATA

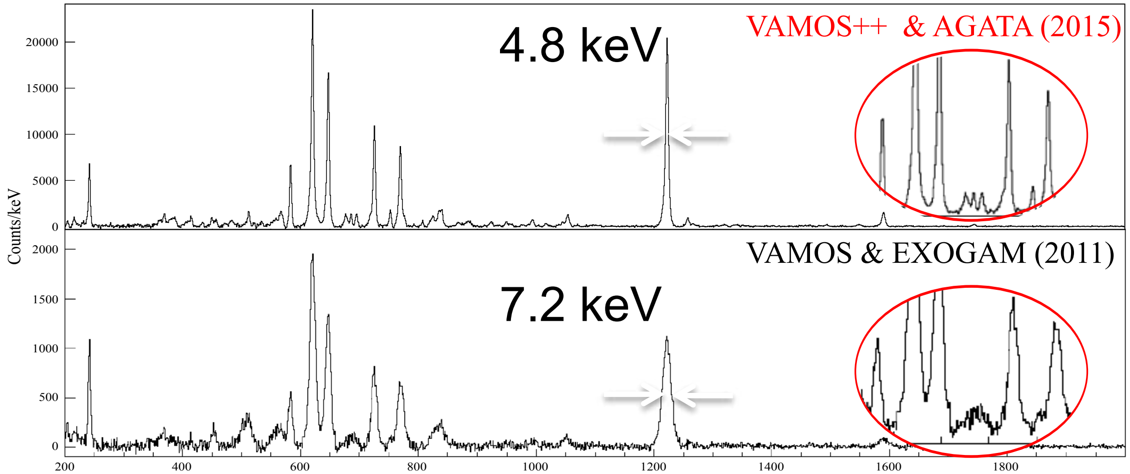
Response to high-multiplicities (Mγ=30)



P.G. Bizzeti, Eur. Phys. J. A51 (2015) 49



Polarization sensitivity

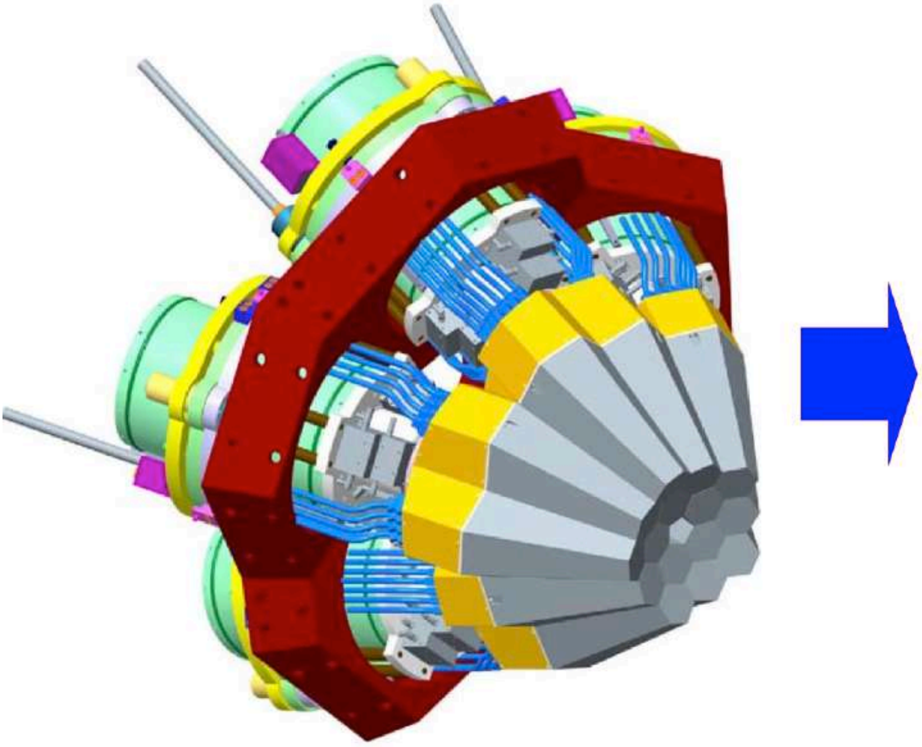


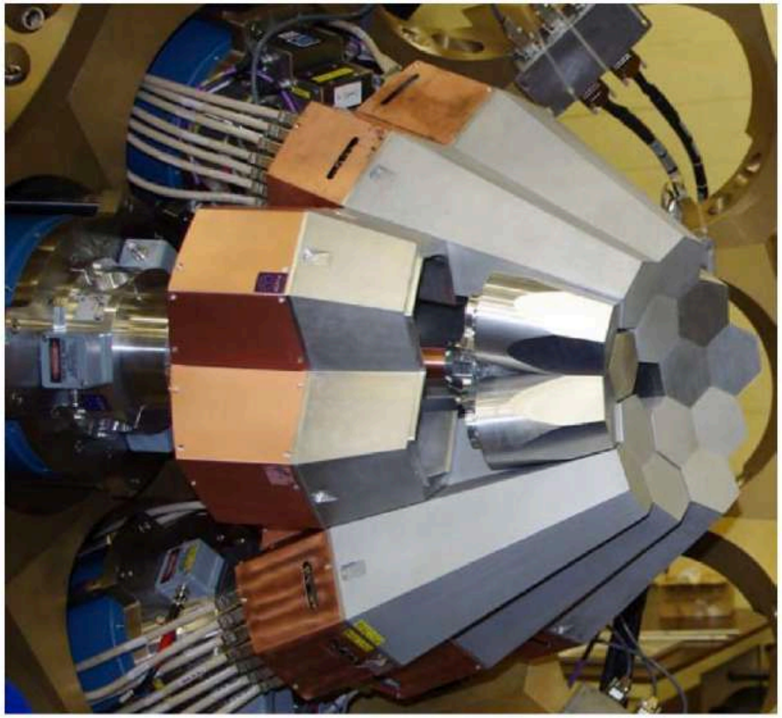
Doppler correction capability (^{98}Zr, v/c~10%)

DEMONSTRATOR PHASE (2003-2008)

MoU signed in 2002 by 12 European countries

5 triple clusters, online PSA & tracking, in-beam commissioning at Legnaro





Agata Technical Design Report (2008, http://npg.dl.ac.uk/agata_acc/publications_documentation/TDR_EUJRA.pdf)

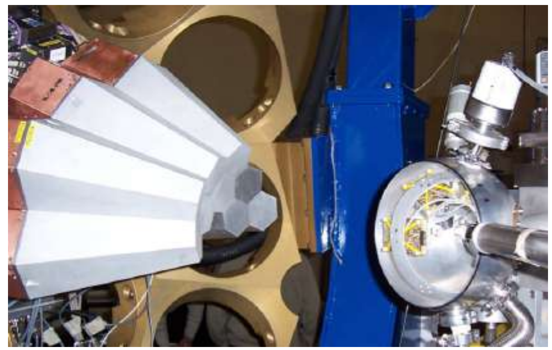
AGATA – Advanced GAmma Tracking Array: S. Akkoyun et al., Nucl. Instr. Meth. A 668 (2012) 26–58

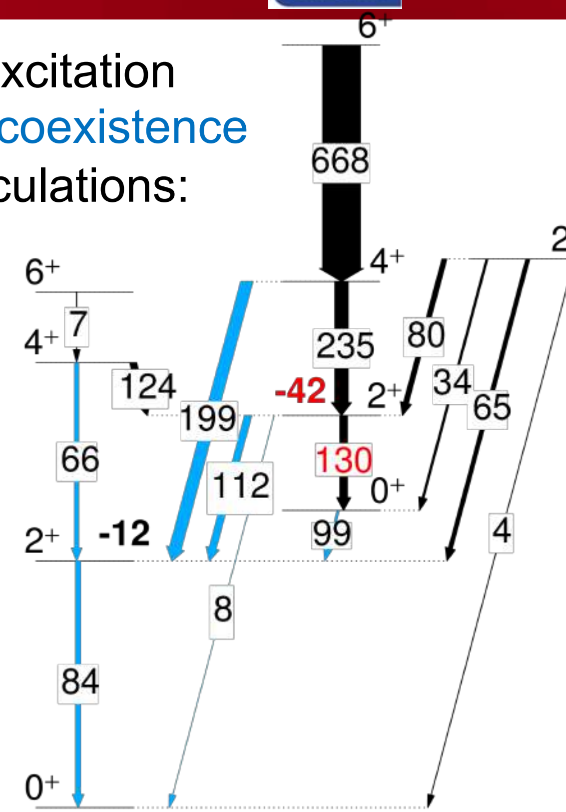
Superdeformed and triaxial states in ^{42}Ca

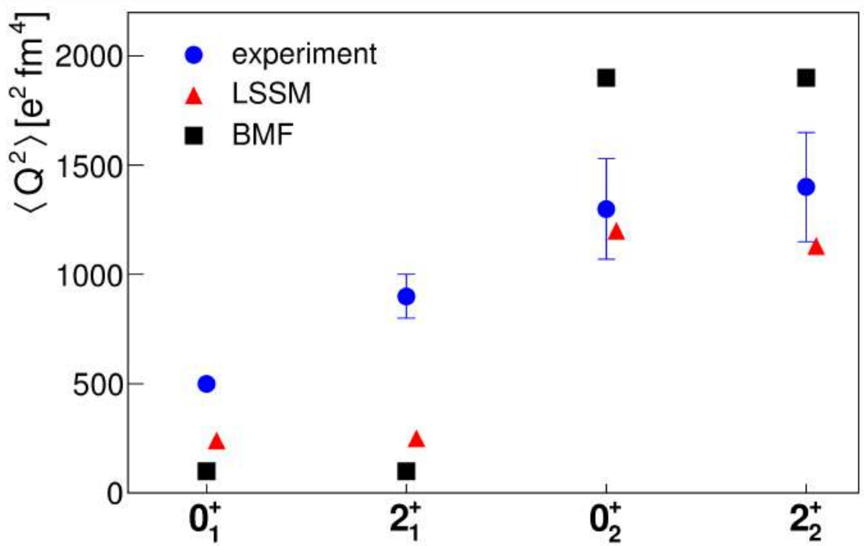
First "regular" experiment with AGATA – led by IFJ PAN and HIL Warsaw

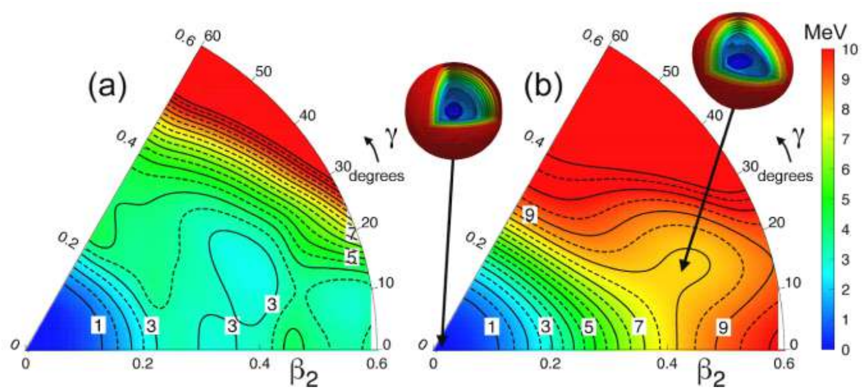
- first population of a superdeformed band via Coulomb excitation
- satisfactory description of the observed extreme shape coexistence with large-scale shell model and beyond-mean-field calculations:

AGATA + DANTE
LNL, April 2010









K. Hadyńska-Klęk *et al,* PRL 117 (2016) 062501;
PRC 97 (2018) 024326

CONSTRUCTION PHASE 1 (2009-2020)

MoU signed in 2009 and renewed in 2015

15 detectors

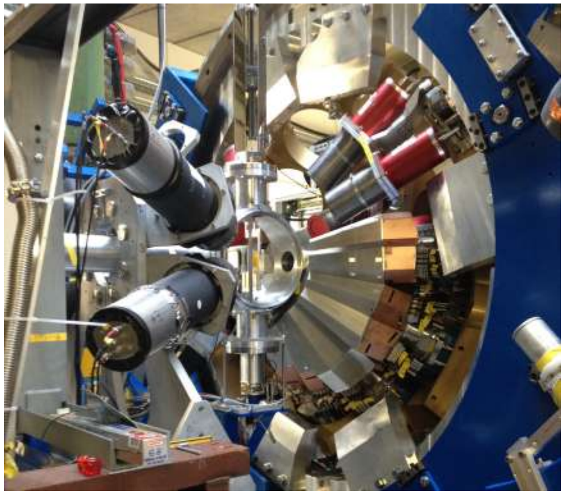
LNL

Coupled to the magnetic spectrometer PRISMA

22 detectors

GSI

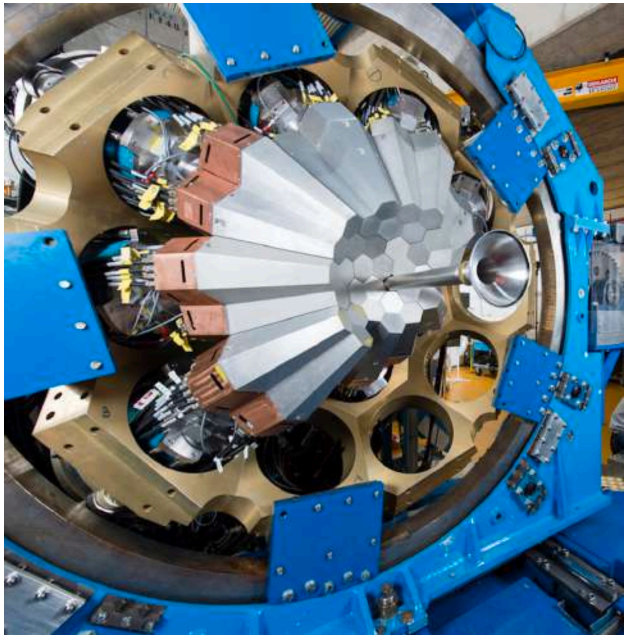
Fast radioactive beams coupled to LYCCA



41 detectors (2019)

GANIL

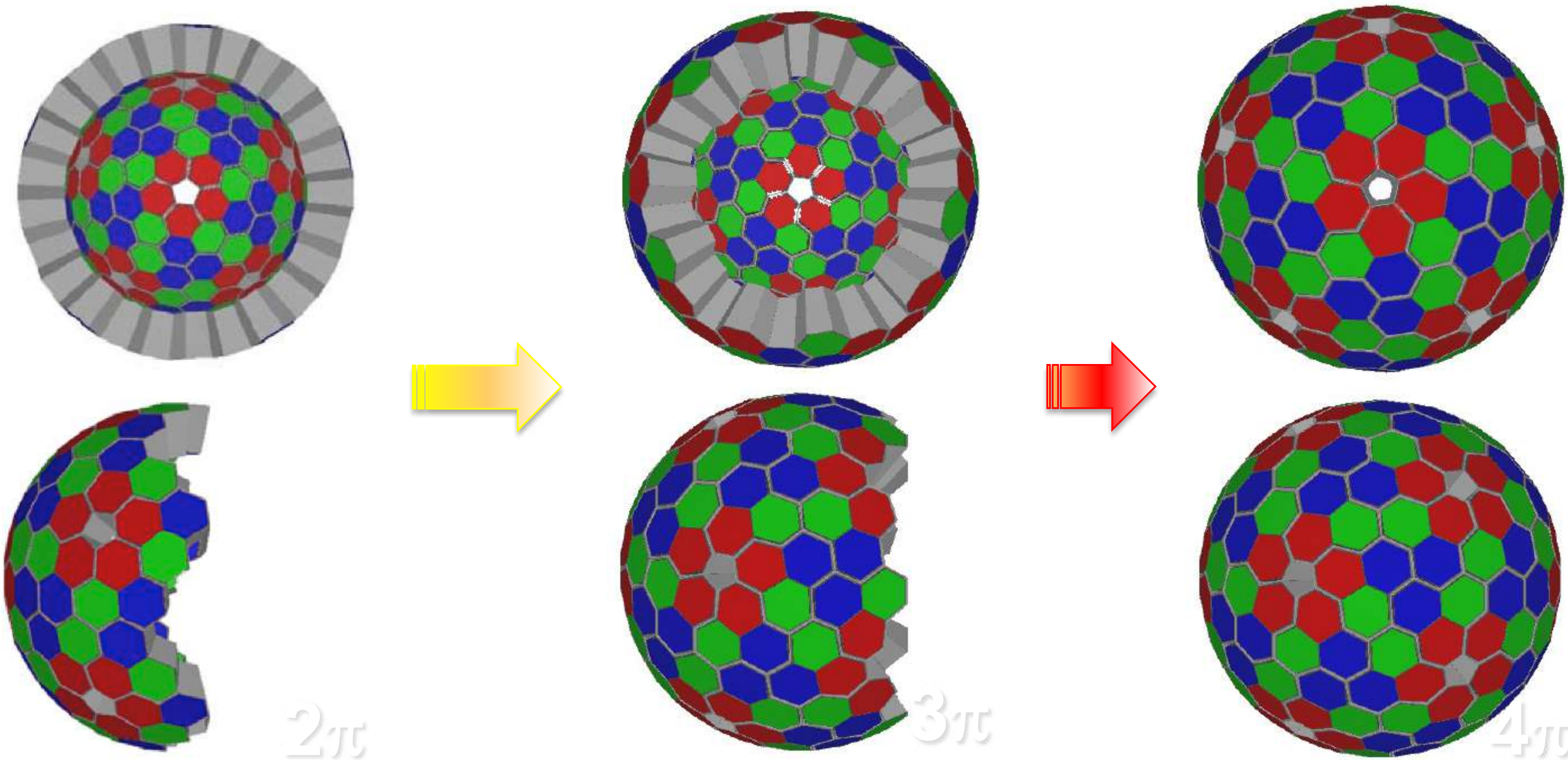
Coupled to VAMOS, NEDA/N-Wall, DIAMANT, FATIMA, PARIS, MUGAST



LNL 2010-2011 → **GSI 2012-2014** → **GANIL 2015-2021**

~60 weeks of beam on target, 62 scientific and 56 technical papers since 2010

AGATA upgrade to 4π in 2030: timeline



Stable beams & accelerated ISOL beams	Radioactive ion beams (projectile fragmentation & fission)	Stable beams & accelerated ISOL beams
LNL 2022-2025?	**FAIR/ISOLDE 2026?-2028?**	**JYFL/GANIL 2029-2030 ?**

AGATA UPGRADE TO 4π IN 2030: TIMELINE

New MoU being signed:

- Adding AGATA Resource Review Board in the management structure
- Complete AGATA 4π until ~2030
  - Sensitivity ~20 times better than AGATA 1π (for $\gamma\gamma$ coincidences)
  - Only a 4π array delivers optimal tracking performance

    Strong support in NUPECC LRP

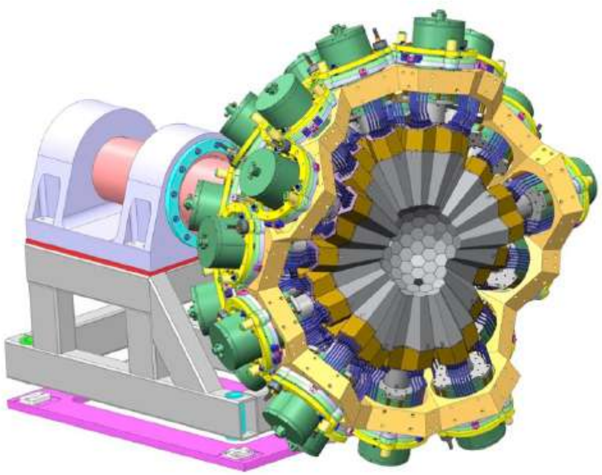
Unique capabilities of AGATA should be comined with strengths of specific laboratories:

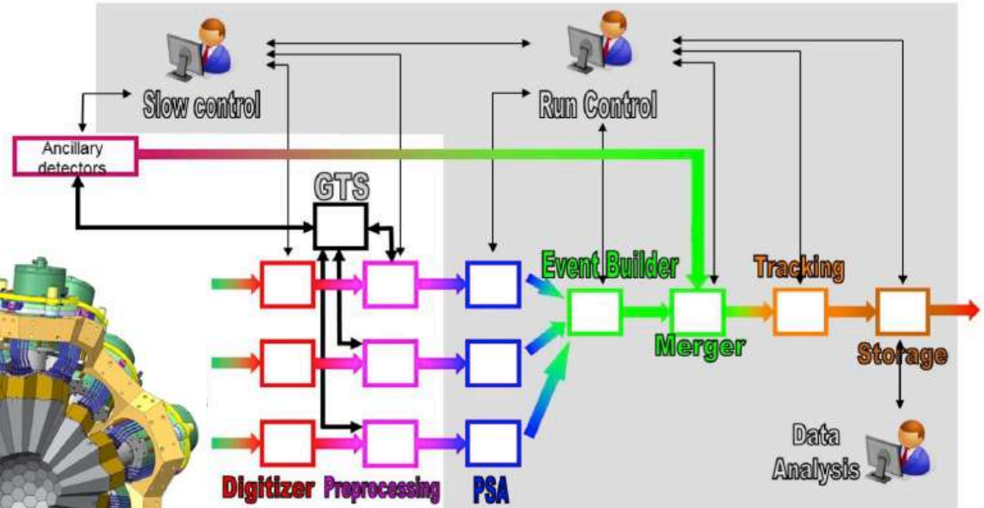
- LNL : stable beams 2022, radioactive beams from SPES 2025 -
- SPIRAL1/SPIRAL2, GANIL: stable beams up to ^{238}U, radioactive beams
- HIE-ISOLDE, CERN: largest variety of exotic ISOL beams
- JYFL: intense stable beams for VHN studies
- FAIR, GSI: exotic relativistic beams

AGATA White Book: W. Korten et al, EPJ A 56, 137 (2020)

AGATA UPGRADE – TECHNICAL DEVELOPMENTS

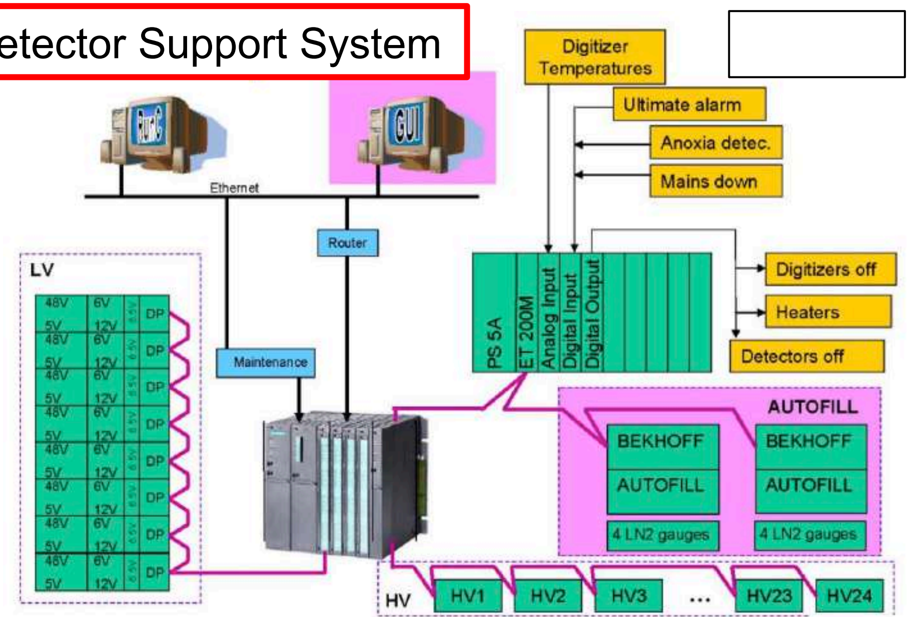
New honeycomb holding & detector-mounting structures

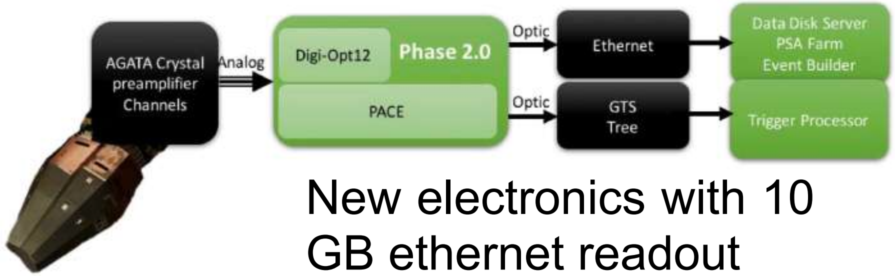




Upgraded DAQ based on NARVAL/ DCOD & improved algorithms

New Detector Support System



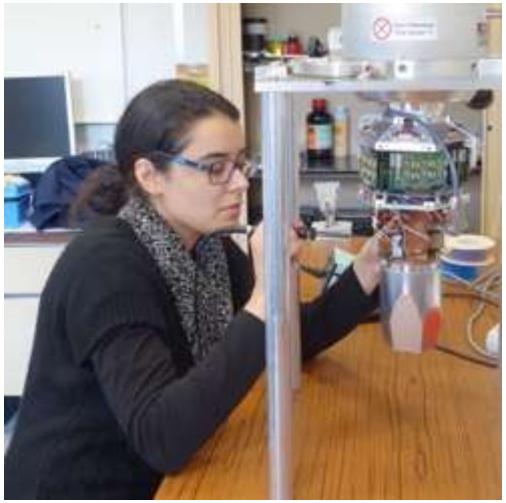


New electronics with 10 GB ethernet readout

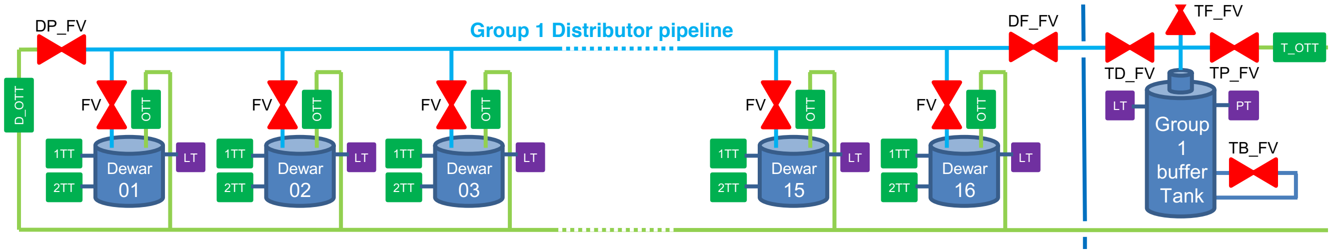
CEA SACLAY IN THE AGATA PROJECT

- Strong physics programme making use of specific strengths of each host laboratory

- AGATA detector laboratory at Saclay: tests of new and repaired AGATA and DEGAS capsules (up to 4 per year); Factory Acceptance Tests at Mirion/Lingolsheim



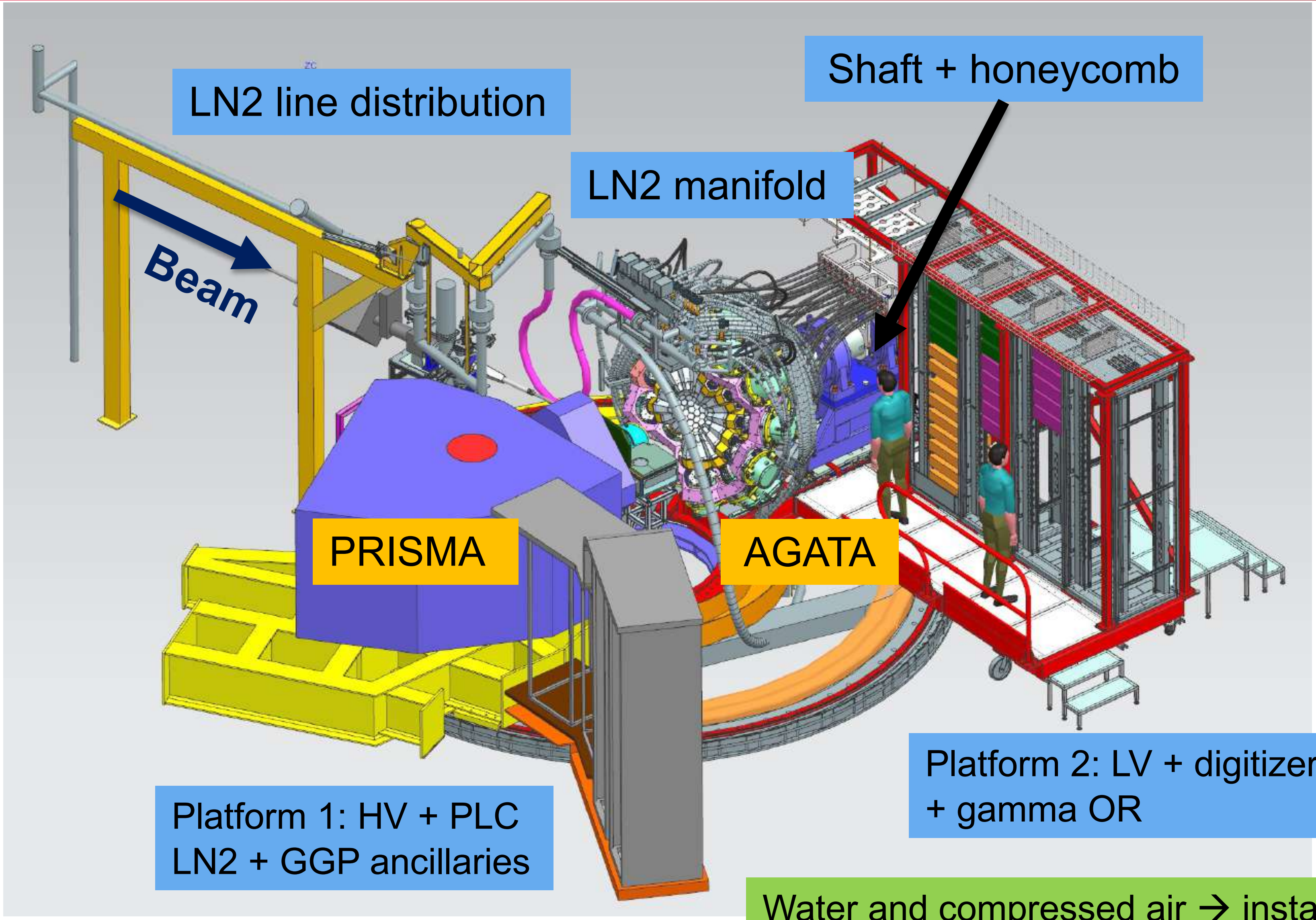
- Development, maintenance and upgrading:
  - low-voltage power supplies and related cabling
  - LN2 filling system



PRISMA HALL BEFORE INSTALLATION WORK

Slide courtesy R. Menegazzo

Layout of Local Infrastructure



Water and compressed air → installed
Power distribution → in progress

Design INFN - Padova
Slide courtesy R. Menegazzo

BIG ARRIVALS

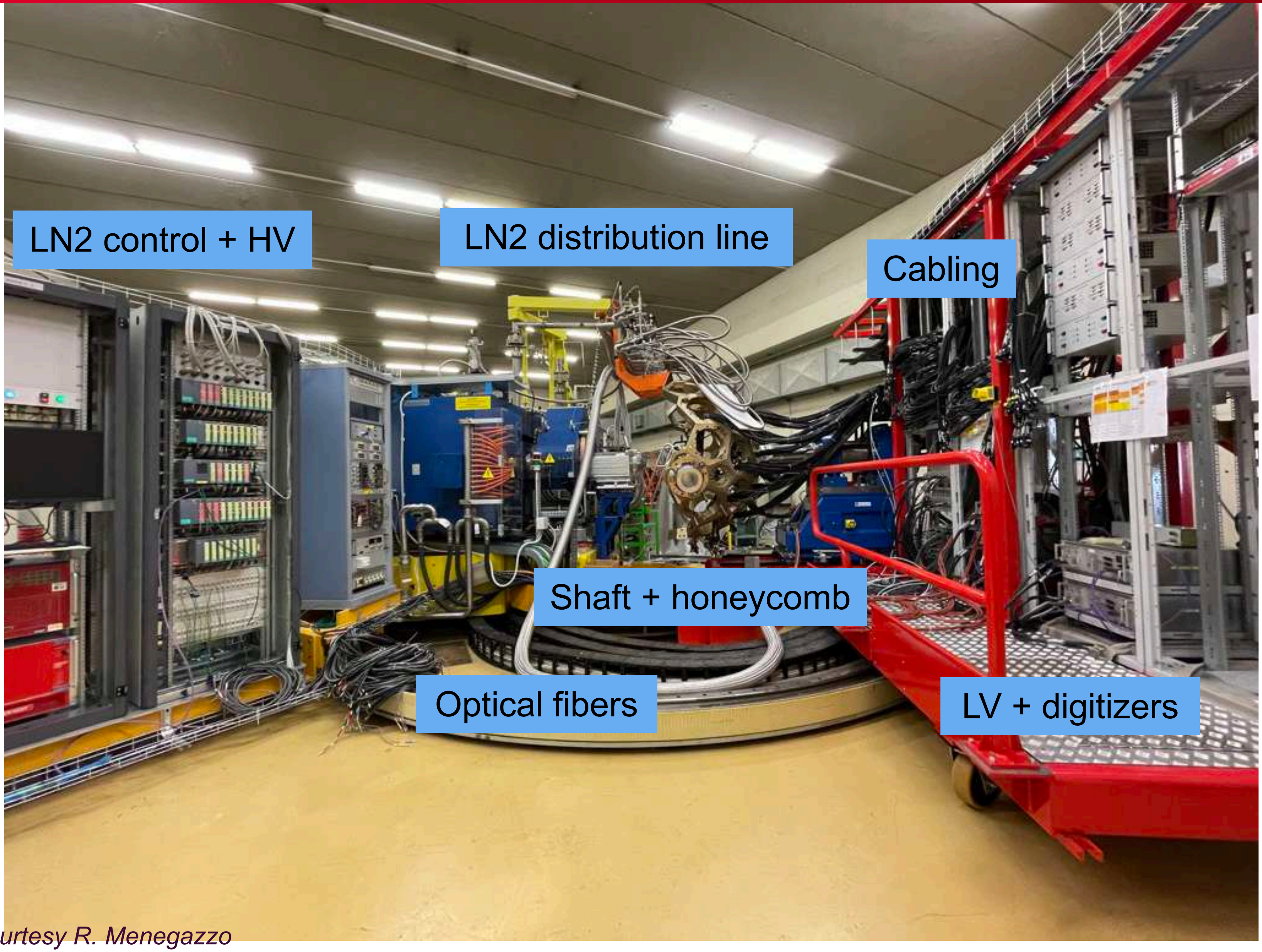
From France (GANIL)
September 8th 2021

From UK (Daresbury)
October 12th 2021

Flanges realized within INFN

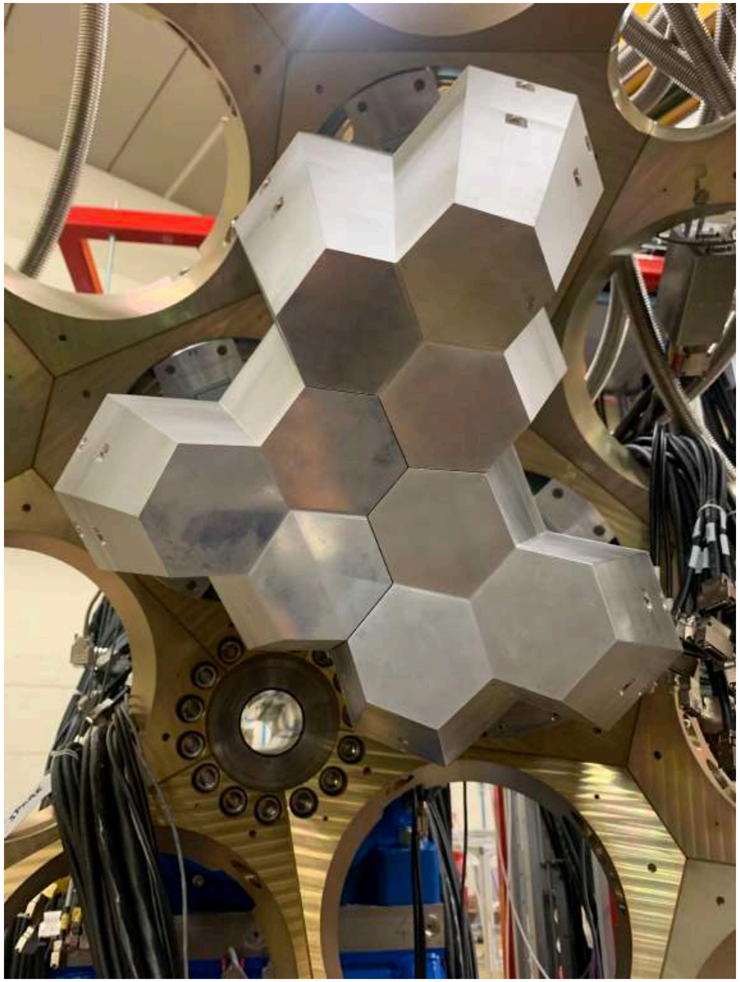
Slide courtesy R. Menegazzo

February 2022 status



Slide courtesy R. Menegazzo

MARCH 2022 STATUS



New ATC alignment and installation tools developed by Daresbury

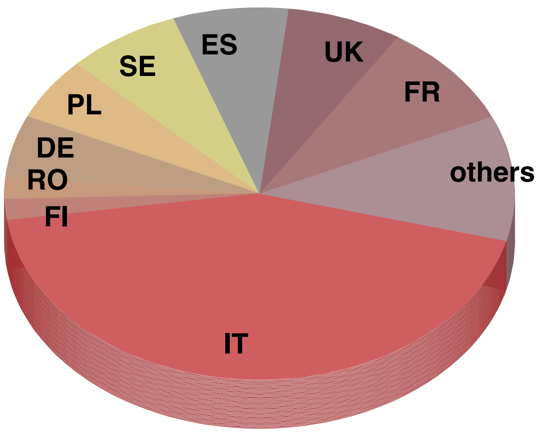
First three ATCs aligned on the structure to <0.1mm (early March)

New Autofill used to supply them with LN_2

7 more ATCs operational, waiting for last adjustments of the Autofill (around Easter)

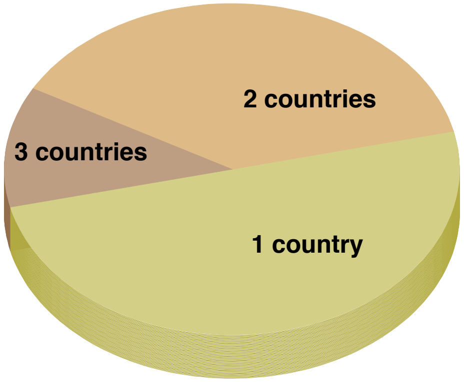
13 ATCs expected for the first physics campaign

overwhelming response from the community: 34 LoIs submitted



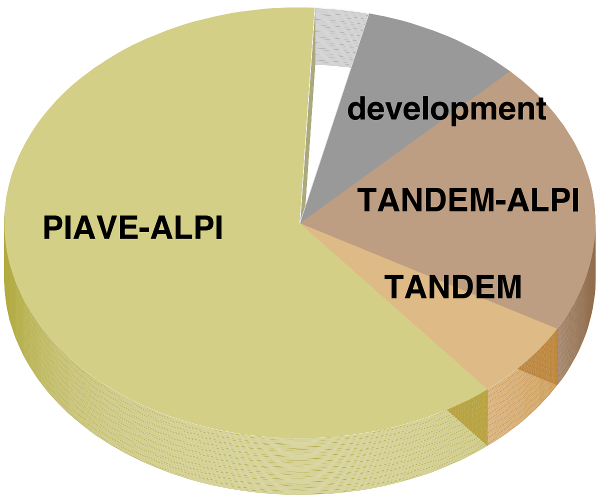
- large majority (24) with at least one Italian spokesperson
- 9 out of 13 countries of the AGATA collaboration represented by LoI
- spokespersons
- co-spokespersons from Croatia, Belgium, Norway, US, Australia

56 persons from 14 countries act as spokespersons



EXPERIMENTAL CONSTRAINTS FOR THE FIRST CAMPAIGN

- stable beams from the Tandem-ALPI-PIAVE complex ancillaries compatible with PRISMA
- ready to run in 2022 (excludes projects that need long-term beam
- development or detectors used elsewhere in 2022 (e.g. PARIS))



- certain developments needed to achieve requested currents, energies, or deliver the requested element – not before 2023; some beams (Hg) not possible

- large majority of projects requested ALPI and/or PIAVE beams

In total, about 300 days of beamtime requested

After the Pre-PAC meeting

- overlaps between certain projects (around ^{68}Ni, ^{208}Pb, ^{34}Si) - proponents strongly encouraged to collaborate
- no authorisation to use actinide targets (4 projects affected)
- call for proposals, December 11, 2021 – only TANDEM beams available before autumn 2022

⇒ we decide to authorise submission of proposals for AGATA with TANDEM beams, which have not been discussed at the Pre-PAC

- 27 AGATA projects + commissioning proposed to the PAC, for a total of 227 days (151 TANDEM only, 137 involving ALPI and/or PIAVE)
- PAC meeting February 21 – 24, 2022:
  8 AGATA experiments + commissioning accepted with priority A,
  5 more with priority B

PRIORITY A EXPERIMENTS WITH AGATA

- Pathway to nuclear structure in heavy neutron rich nuclei in the vicinity of N = 126 and nuclei northwest of ^{132}Sn via multinucleon transfer reactions (P. Reiter) – 7 days
- Evolution of the mixing between single-particle and intruder configuratios approaching the island of inversion at N = 20 (F. Galtarossa, A. Gottardo) – 6 days
- Coexisting shapes and precision tests of Monte-Carlo Shell-Model calculations in ^{96}Zr (N. Marchini, D.T. Doherty, M. Zielińska) – 4 days
- Fusion-fission for γ-ray spectroscopy of neutron-rich nuclei around N = 50 (A. Gottardo, M. Caamaño, D. Ramos, J.J. Valiente-Dobón) – 14 days
- Search for a Josephson-like effect in the ^{116}Sn + ^{60}Ni system (L. Corradi, S. Szilner) – 14 days
- Probing multiple shape coexistence in ^{110}Cd with Coulomb excitation (M. Zielińska, **K. Wrzosek-Lipska**, A. Nannini, M. Rocchini, P. Garrett) – 5 days
- Understanding the nature of 0^+ states in ^{110,112}Sn and ^{108}Cd (N. Marginean, **M. Ciemała**, F. Crespi) – 12 days

Priority A experiments with AGATA - tests and commissioning

- Test of particle-γ coincidences with Agata+Euclides for studies of light-ion fusion at astrophysical energies (G. Montagnoli, A.M. Stefanini) – 3 days

- Test of the ^{70}Zn-^{64}Ni alloy target for nuclear structure studies in the vicinity of Z=28 neutron-rich isotopes with AGATA and PRISMA (R.M. Perez Vidal, S. Bottoni, E. Sahin, A. Illana, J. Benito, J. Ljungvall) – 3 days

- Commissioning of AGATA and complementary detectors at LNL (F. Crespi, F. Galtarossa, J. Pellumaj, M. Rocchini, M. Sedlak) – 15 days (split over 3 runs)

  - AGATA + PRISMA + DANTE
  - AGATA + SPIDER + DANTE
  - reverse Plunger

blue – TANDEM only (45 days + 9), red – needs ALPI and/or PIAVE (38 days + 11))

PRIORITY B EXPERIMENTS WITH AGATA

- Delineating the island of shape coexistence in *N* ~ *Z* nuclei around *A*=70 through Coulomb excitation of ^{74}Se (W. Korten, **K. Wrzosek-Lipska**, E. Clément) – 5 days

- Establishing the properties of ^{19}Ne cluster states important for X-ray bursts (C. Wheldon, T. Kokalova) – 7 days

- Investigating the nature of the low-lying states of 196Os via lifetime measurements (D. Brugnara, J. Pellumaj, M. Sedlak) – 11 days

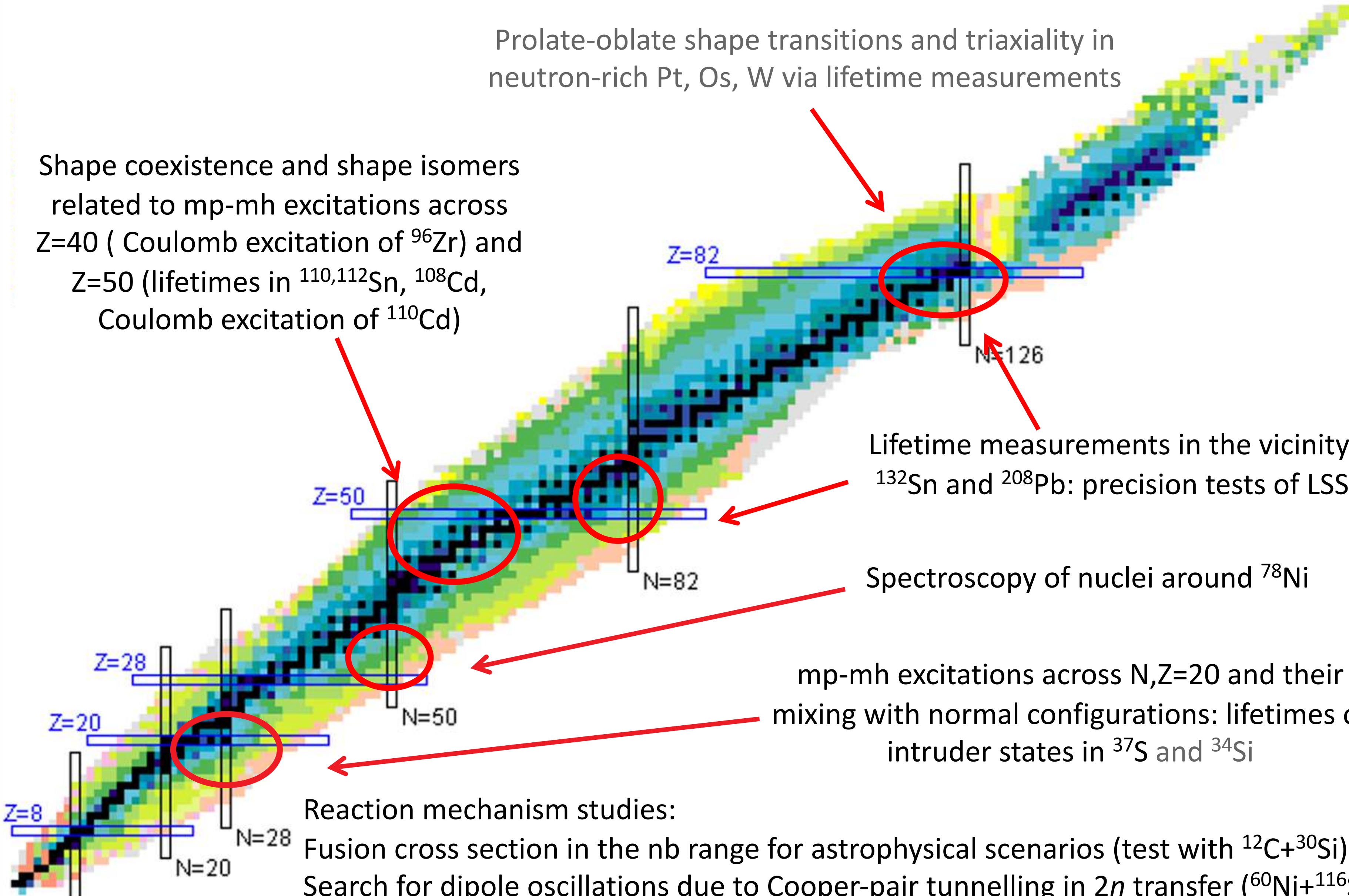
- Lifetime measurements for intruder states towards the island of inversion along the *N*=20 shell closure (I. Zanon, D. Brugnara) – 8 days

- Isospin mixing in the *N*=*Z*=36 ^{72}Kr: Lifetime measurement of the *E*1 isospin forbidden transitions (G. de Angelis, B. Rubio) – 12 days

PHYSICS CASES FOR THE FIRST CAMPAIGN

Prolate-oblate shape transitions and triaxiality in neutron-rich Pt, Os, W via lifetime measurements

Shape coexistence and shape isomers related to mp-mh excitations across Z=40 (Coulomb excitation of ^{96}Zr) and Z=50 (lifetimes in ^{110,112}Sn, ^{108}Cd, Coulomb excitation of ^{110}Cd)



Lifetime measurements in the vicinity of ^{132}Sn and ^{208}Pb: precision tests of LSSM

Spectroscopy of nuclei around ^{78}Ni

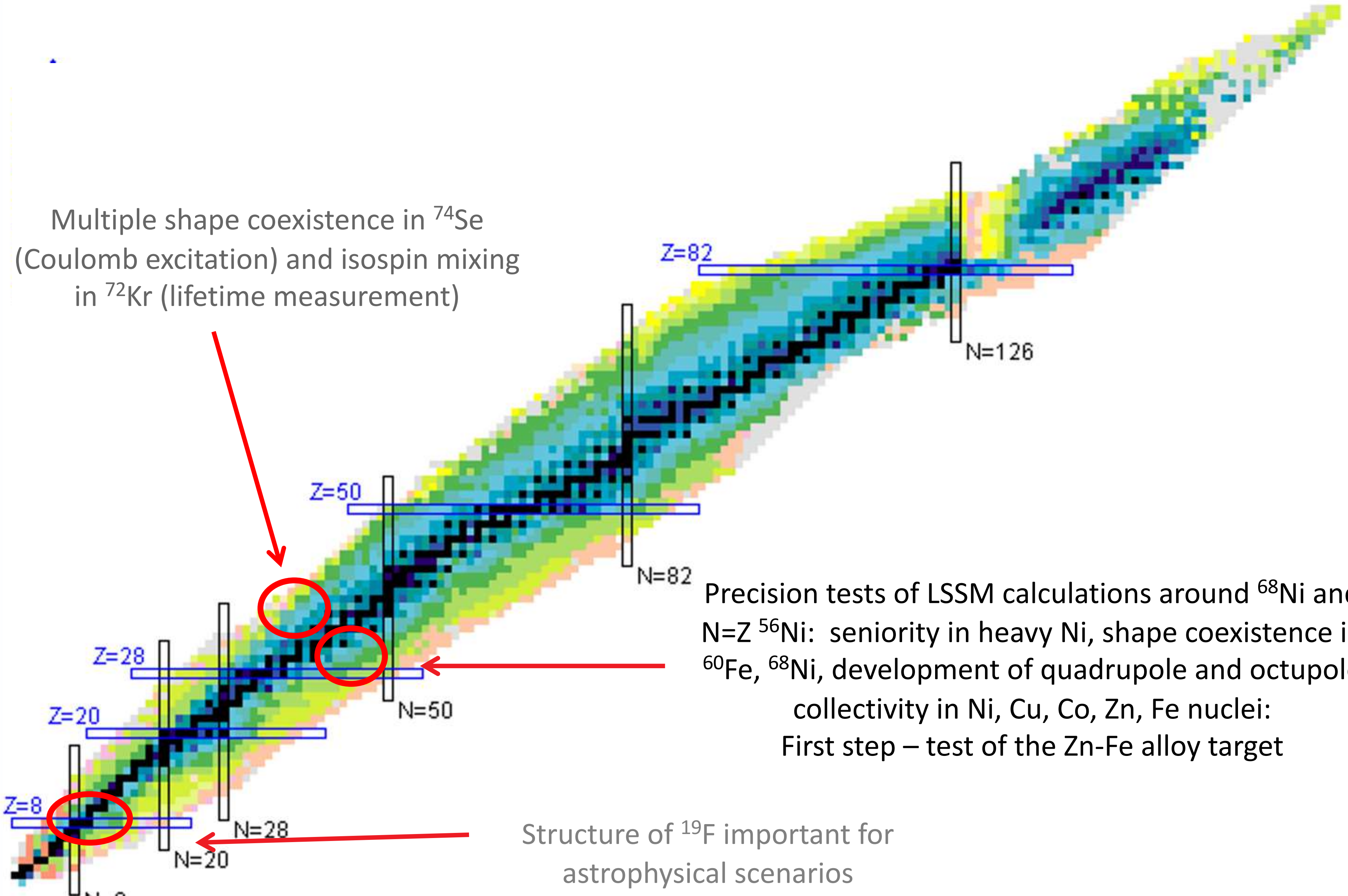
mp-mh excitations across N,Z=20 and their mixing with normal configurations: lifetimes of intruder states in ^{37}S and ^{34}Si

Reaction mechanism studies:

Fusion cross section in the nb range for astrophysical scenarios (test with ^{12}C+^{30}Si)

Search for dipole oscillations due to Cooper-pair tunnelling in 2*n* transfer (^{60}Ni+^{116}Sn)

PHYSICS CASES FOR THE FIRST CAMPAIGN

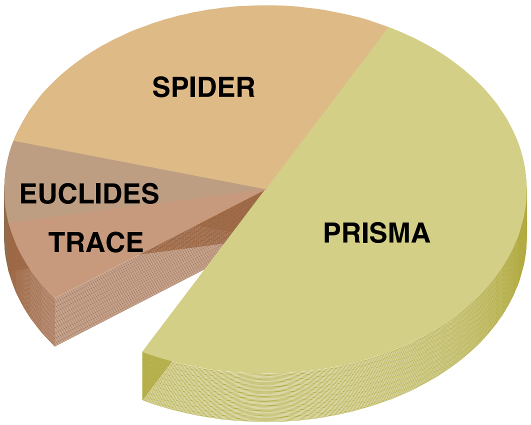


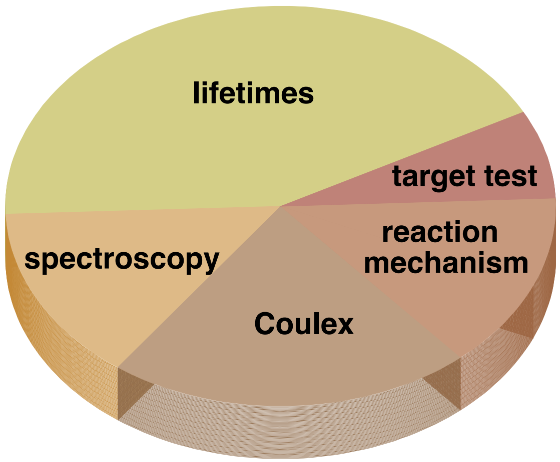
Multiple shape coexistence in ^{74}Se (Coulomb excitation) and isospin mixing in ^{72}Kr (lifetime measurement)

Precision tests of LSSM calculations around ^{68}Ni and N=Z ^{56}Ni: seniority in heavy Ni, shape coexistence in ^{60}Fe, ^{68}Ni, development of quadrupole and octupole collectivity in Ni, Cu, Co, Zn, Fe nuclei:
First step – test of the Zn-Fe alloy target

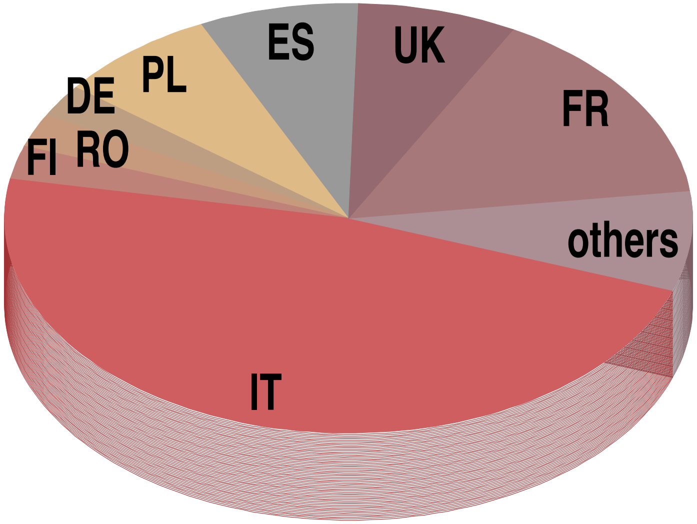
Structure of ^{19}F important for astrophysical scenarios

ACCEPTED PROPOSALS - STATISTICS





- 7 projects out of 14 require PRISMA
- lifetime measurements (RDDS, DSAM) dominate, but there is a fair share of other types of measurements
- spokespersons represent 8 out of 13 countries of the AGATA collaboration – similar distribution as in the LoI phase

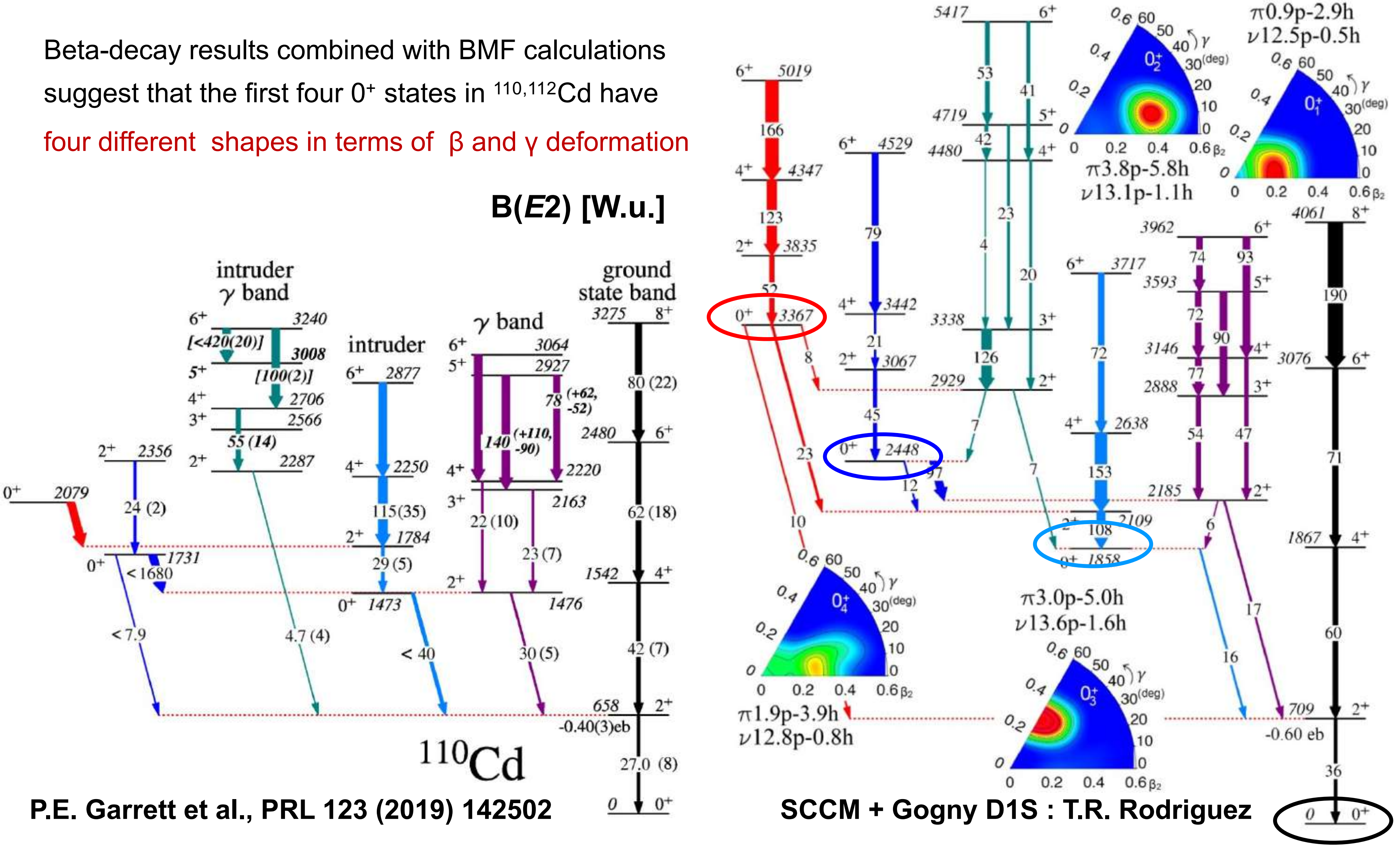


MULTIPLE SHAPE COEXISTENCE IN ^{110}CD

K. WRZOSEK-LIPSKA, P. GARRETT, A. NANNINI, M. ROCCHINI, MZ

Beta-decay results combined with BMF calculations suggest that the first four 0^+ states in ^{110,112}Cd have four different shapes in terms of β and γ deformation

B(*E*2) [W.u.]



P.E. Garrett et al., PRL 123 (2019) 142502

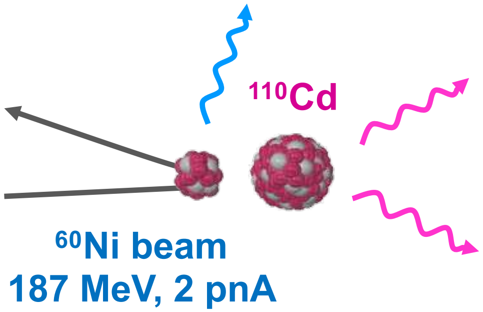
SCCM + Gogny D1S : T.R. Rodriguez

Slide courtesy K. Wrzosek-Lipska

MULTIPLE SHAPE COEXISTENCE IN ^{110}CD

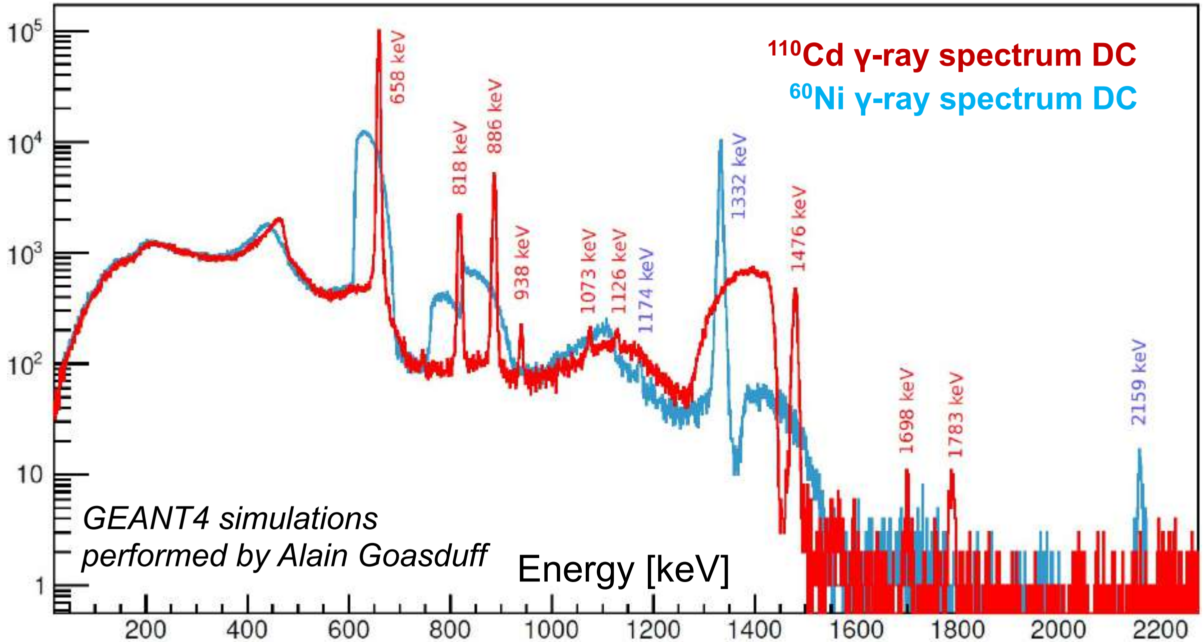
K. WRZOSEK-LIPSKA, P. GARRETT, A. NANNINI, M. ROCCHINI, MZ

Coulomb excitation of ^{110}Cd with SPIDER + AGATA



Measurement complementary to studies with lighter beams (^{32}S, ^{14}N) performed with EAGLE at HIL

Experiment with a ^{110}Cd beam (not authorised at LNL) planned with GRETINA at ANL

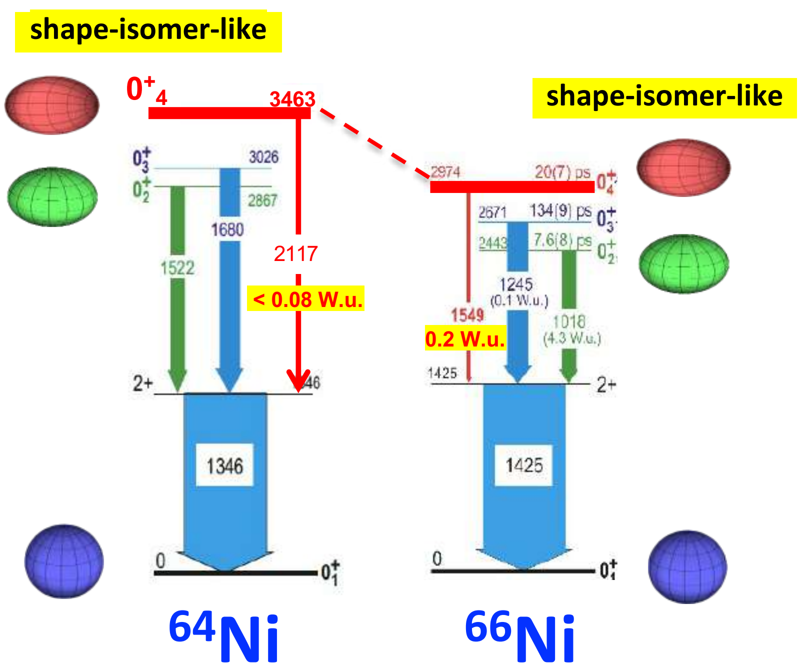


Slide courtesy K. Wrzosek-Lipska

SHAPE ISOMERS IN ^{110,112}SN, ^{108}CD

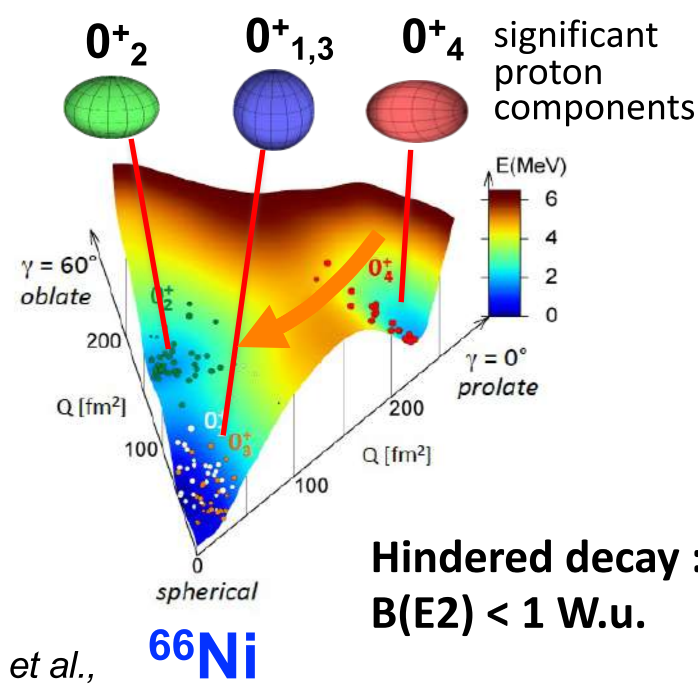
N. MARGINEAN, M. CIEMAŁA, F. CRESPI

Strongly hindered *E*2 decay of 0^+ states in ^{64,66}Ni isotopes observed via lifetime measurements following sub-barrier transfer at IFIN-HH



Monte-Carlo Shell-Model microscopic interpretation

Y. Tsunoda and T. Otsuka



Hindered decay : B(E2) < 1 W.u.

S. Leoni, B. Fornal, M. Sferrazza, N. Marginean *et al.*, Phys. Rev. Lett. 118, 162502 (2017)

N. Marginean, D. Little, Y. Tsunoda, S. Leoni, R.V.F. Janssens, B. Fornal *et al.*, Phys. Rev. Lett. 125, 102502 (2020)

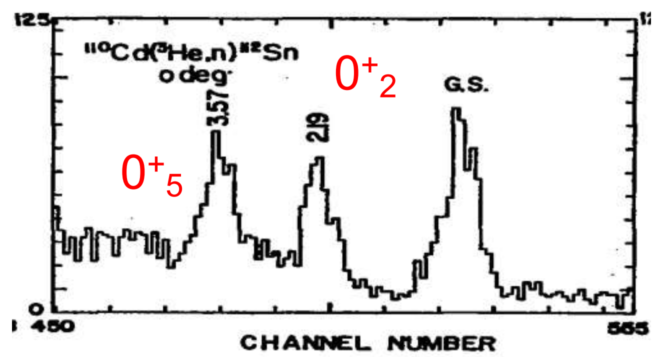
Slide courtesy N. Marginean

SHAPE ISOMERS IN ^{110,112}SN, ^{108}CD

N. MARGINEAN, M. CIEMAŁA, F. CRESPI

- Multiple 0^+ states identified in stable Sn and Cd nuclei
- Some of them strongly populated in 2-proton transfer
- Information on *E*2 transition probabilities insufficient

^{110}Cd(^{3}He,*n*)^{112}Sn, n TOF



enhanced population of 0^+_2 and 0^+_5

- Multinucleon transfer induced by 5-MeV/*A* ^{32}S beam impinging on ^{110}Cd to populate excited states in ^{110,112}Sn, ^{108}Cd
- PRISMA for reaction channel identification
- Spectroscopy (3 days)
- Plunger measurement (11 days) with a 2 mg/cm^2 Ta degrader

Slide courtesy N. Marginean

SEARCH FOR JOSEPHSON-LIKE EFFECT IN THE ^{116}SN-^{60}NI SYSTEM

L. CORRADI, S. SZILNER

PHYSICAL REVIEW C 103, L021601 (2021)

Letter | Editors' Suggestion | Featured in Physics

Quantum entanglement in nuclear Cooper-pair tunneling with γ rays

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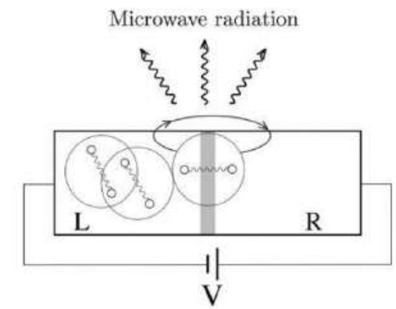
Physics — VIEWPOINT

The Tiniest Superfluid Circuit in Nature

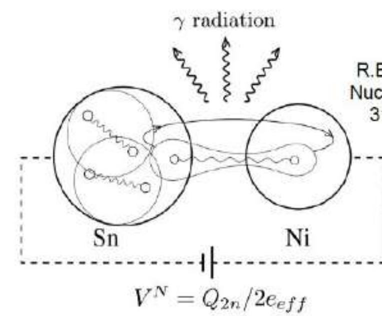
A new analysis of heavy-ion collision experiments uncovers evidence that two colliding nuclei behave like a Josephson junction—a device in which Cooper pairs tunnel through a barrier between two superfluids.

By Piotr Magierski

physics.aps.org | © 2021 American Physical Society | February 25, 2021 | Physics 14, 27 | DOI: 10.1103/Physics.14.27

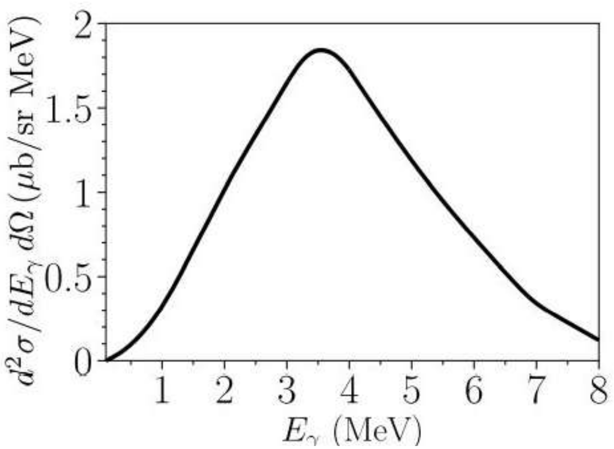


applied voltage



R.Broglia et al, Nucl.Phys.News 31,4 (2021)

reaction Q-value divided by the effective charge of the tunneling Cooper pair



It is predicted that the oscillating motion of the Cooper pairs exchanged between the collision partners will result in emission of EM waves in the region of a few MeV

Figures courtesy L. Corradi

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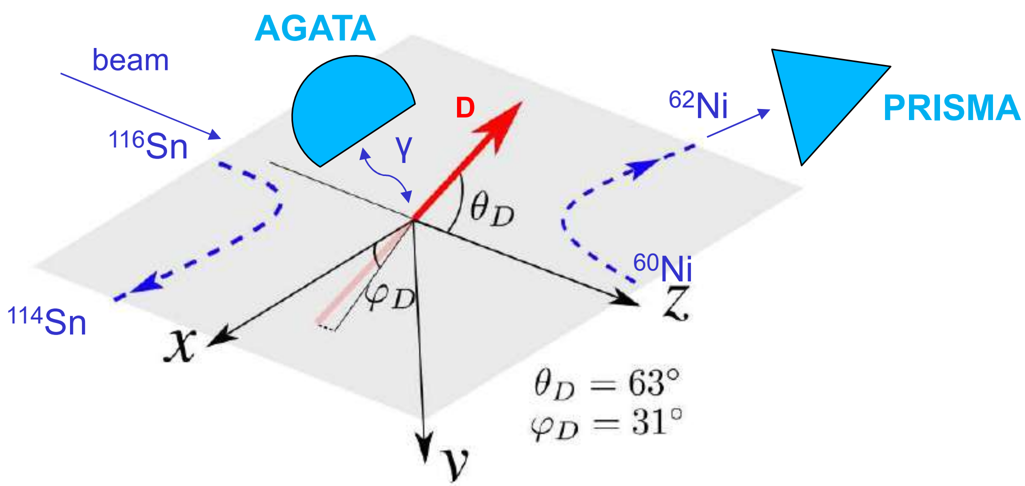
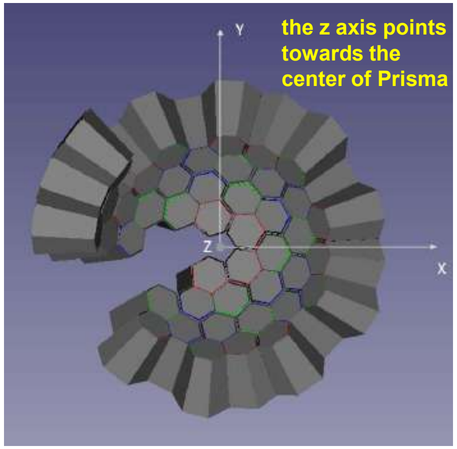
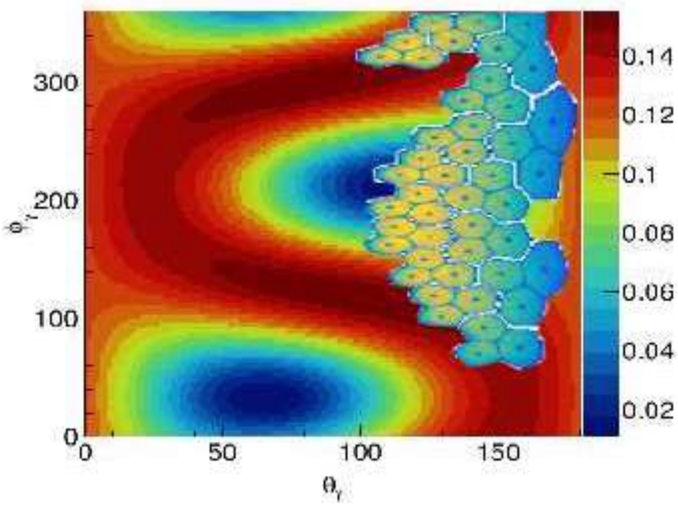
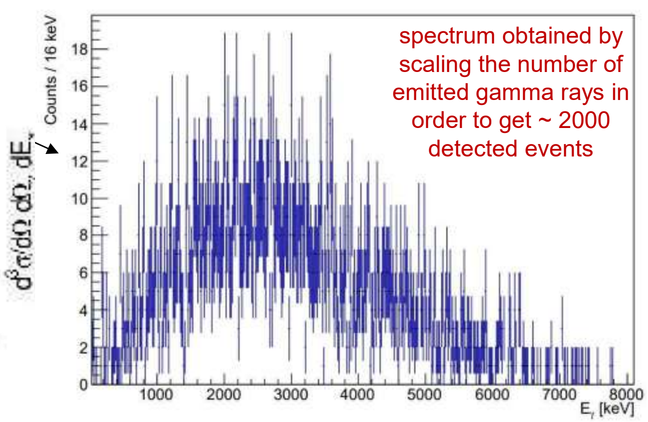


Such radiation observed in previous measurements of the group with the same reaction:
D. Montanari *et al*, PRL 113, 052501 (2014);
D. Montanari *et al*, PRC 93, 054623 (2016)

With AGATA – possible to measure angular distribution

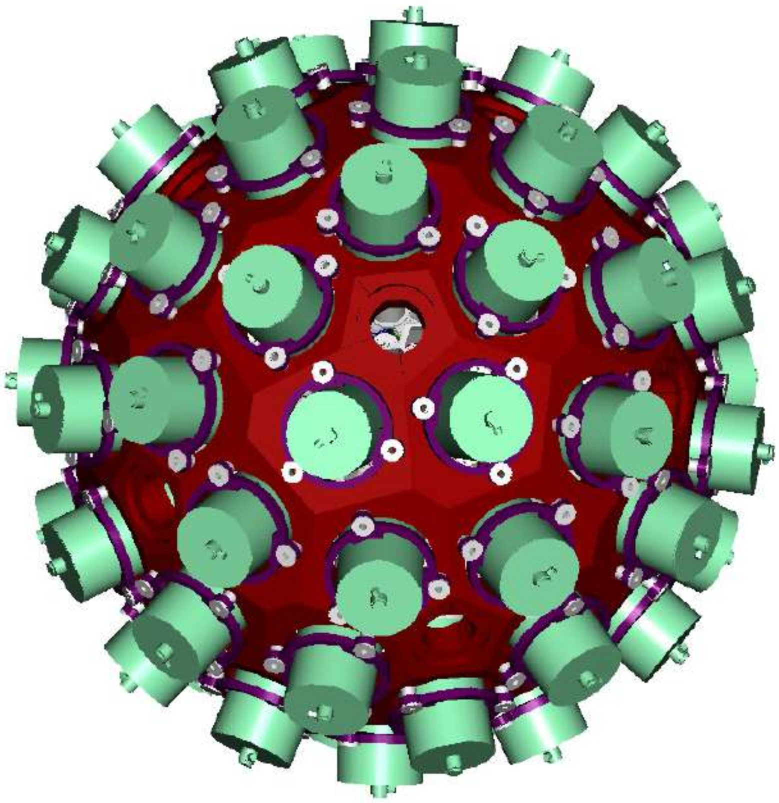






Figures courtesy L. Corradi

CONCLUSIONS



- Preparations of the campaign well advanced
- Commissioning planned in April 2022, experiments starting from May 2022
- May – July 2022 experiments with TANDEM
- October – December 2022 also with ALPI and PIAVE
- Next PAC at the end of 2022 (also ALPI and PIAVE), then spring 2023 (TANDEM only)

We are looking forward to exciting physics!