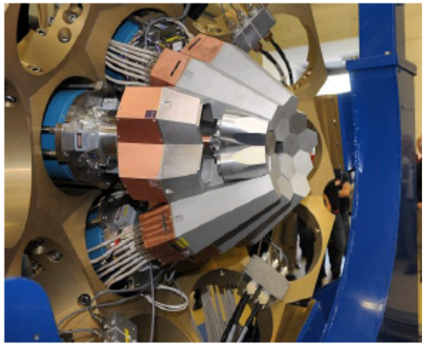
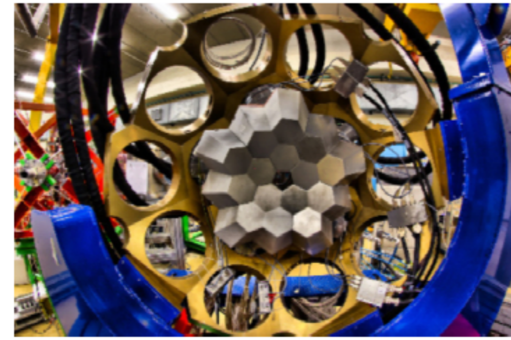




Results of the AGATA campaign in Legnaro

UPDATE

Francesco Recchia

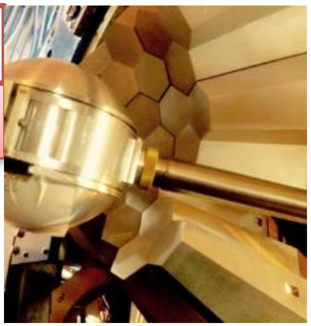
Universita’ di Padova

Outline

LNL
2010-11

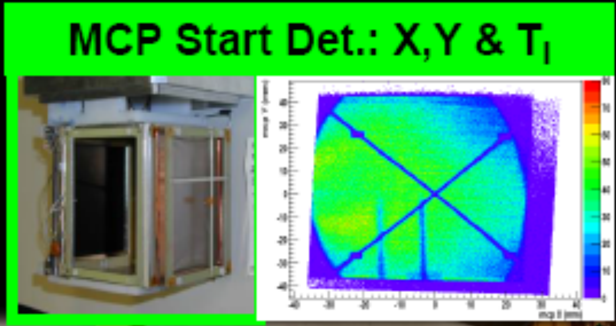
GSI
2012-14

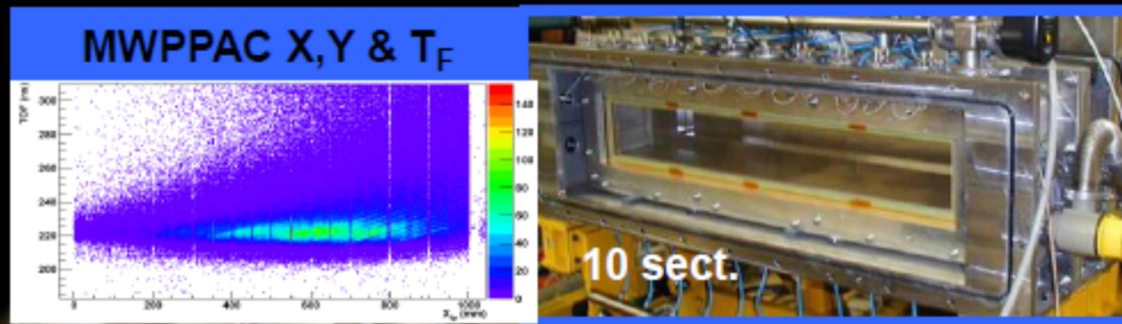
GANIL
2015-

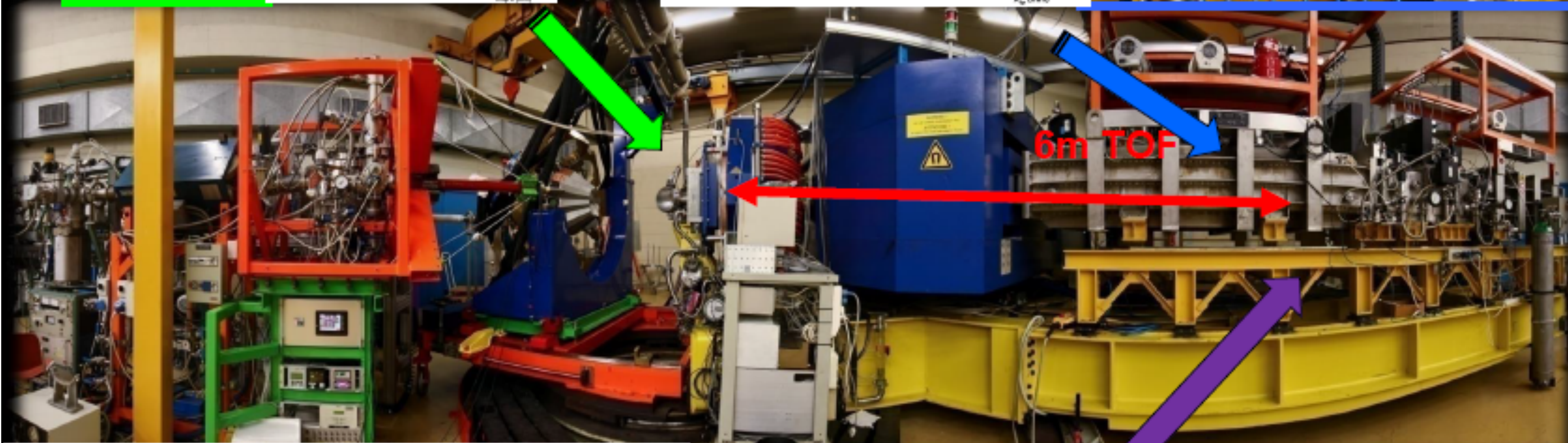


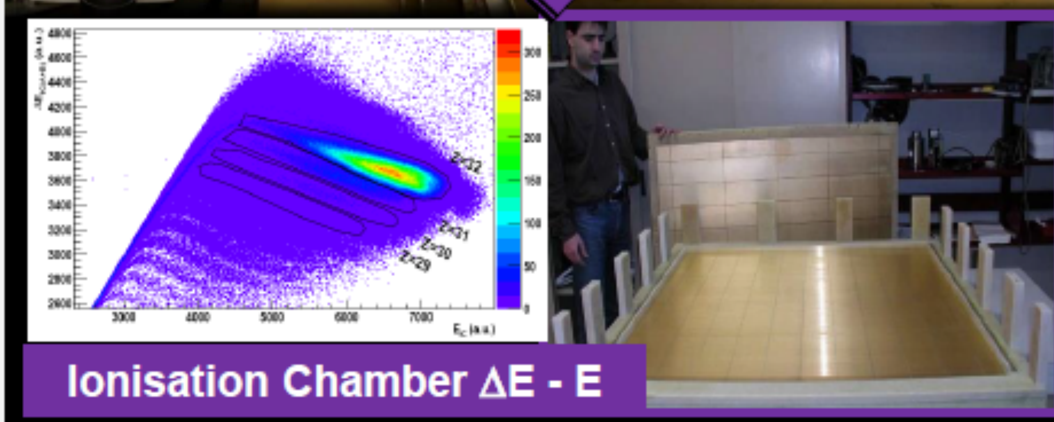
- AGATA demonstration phase
  - Legnaro Demonstration: 2009
  - Physics Campaign: 2010-11
- AGATA construction phase
  - GSI Physics Campaign
  - GANIL Physics Campaign

PRISMA: Tracking Magnetic Spectrometer





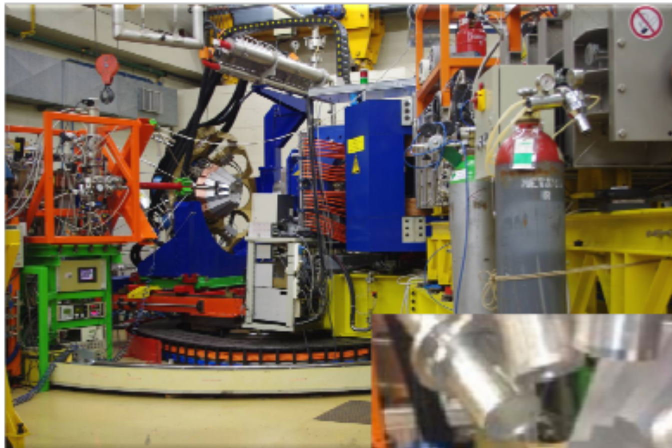


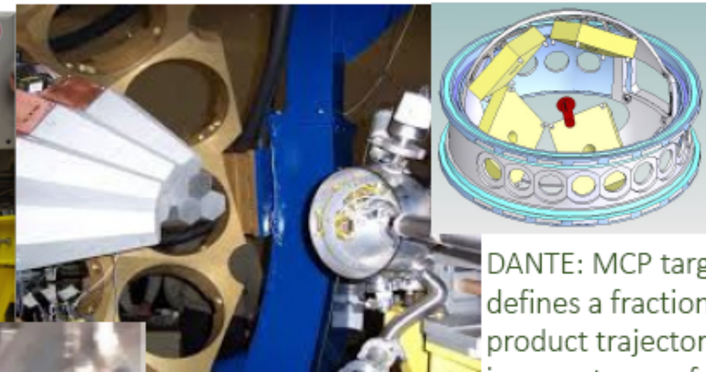


- Large acceptance Ω = 80 msr
- ΔZ/Z ≈ 1/60 (Measured) IC
- Energy ΔA/A ≈ 1/190 (Measured)
- Acceptance ±20%
- Max. Bρ = 1.2 T.m.

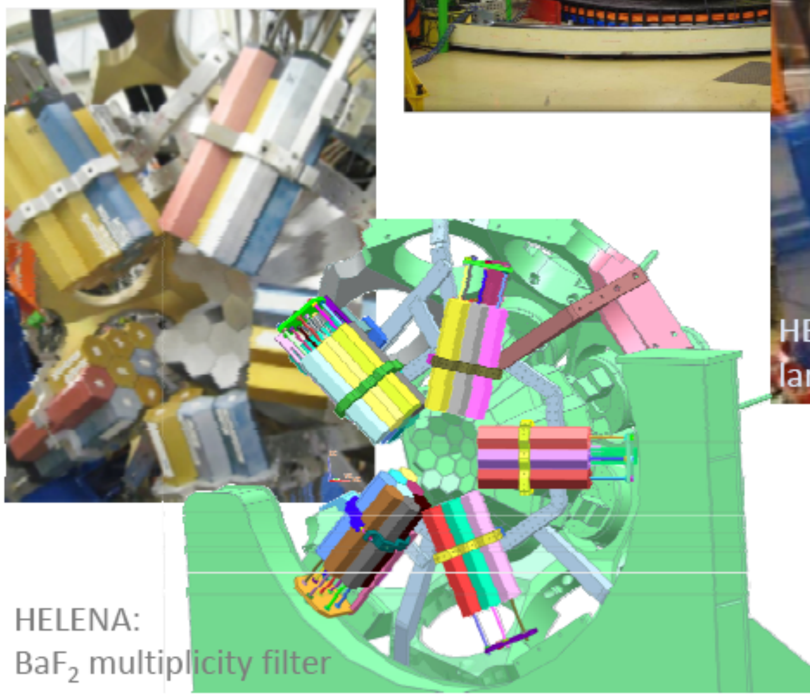
Ancillary Devices

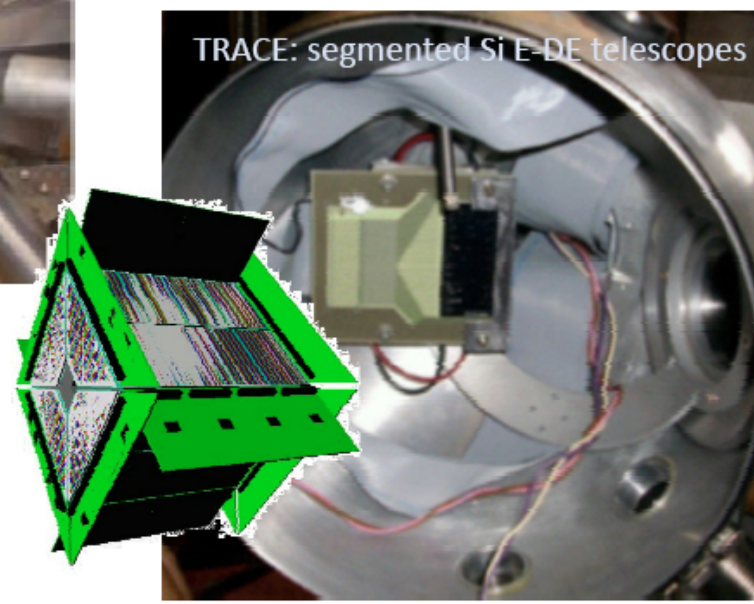
PRISMA: magnetic spectrometer with trajectory reconstruction to identify reaction products





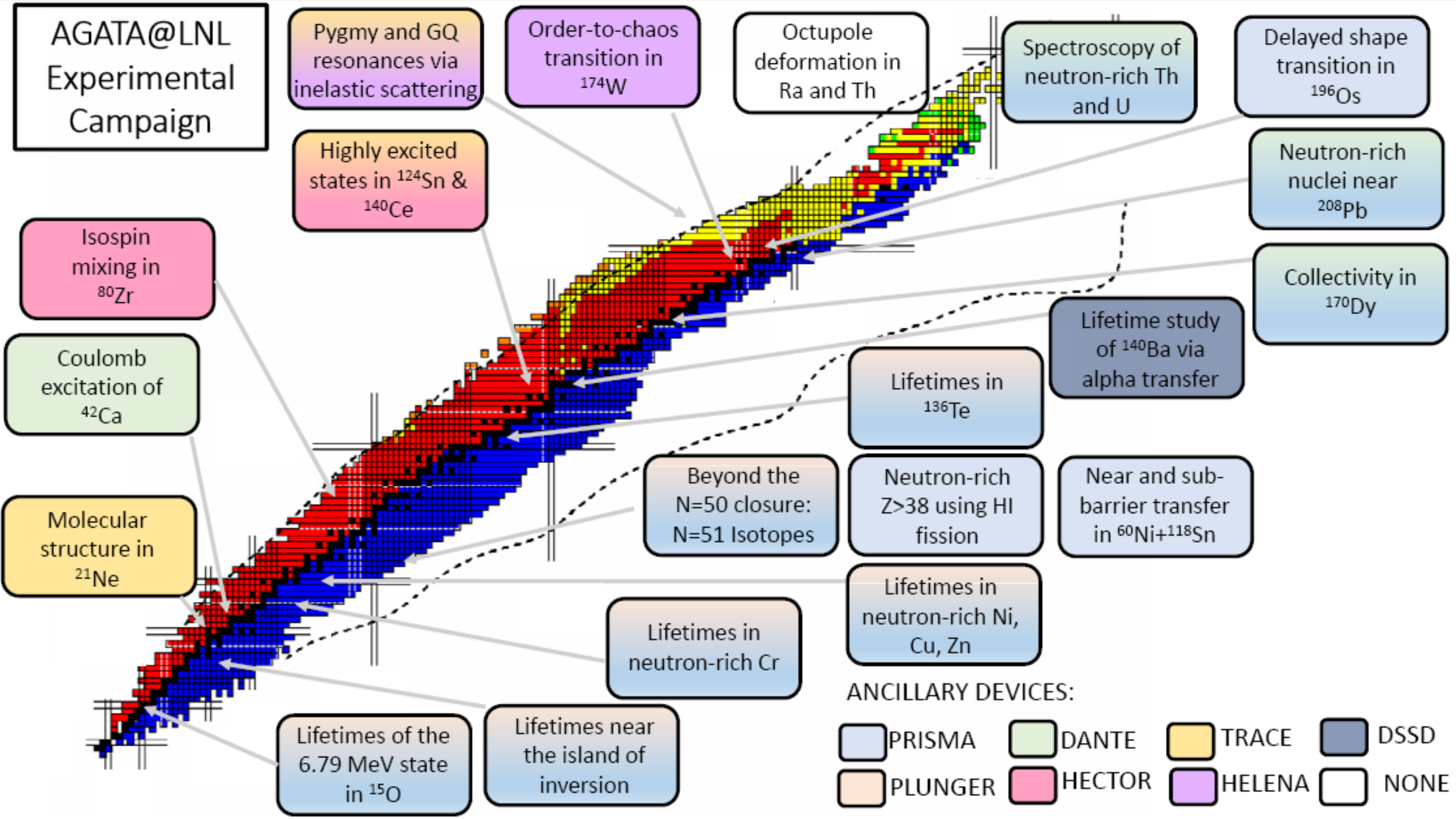
DANTE: MCP target array defines a fraction of product trajectories not in acceptance of PRISMA





HELENA:
BaF_2 multiplicity filter

AGATA@LNL Experimental Campaign

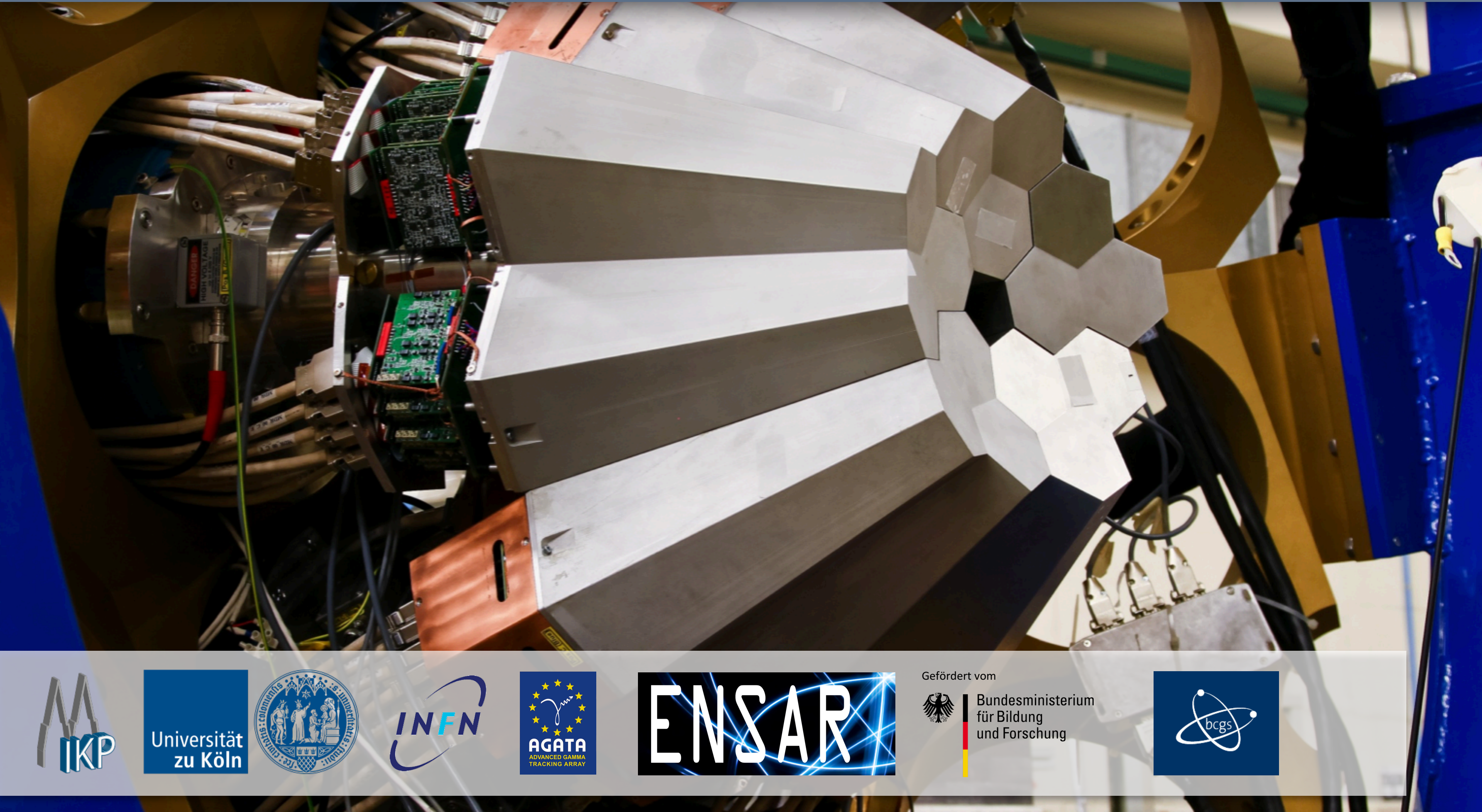


20 approved exp with a total of 142 days (about 3500 hours) approved

Multinucleon-transfer reactions as a gateway to nuclei near the $N = 82$ and $Z = 50$ shell closures

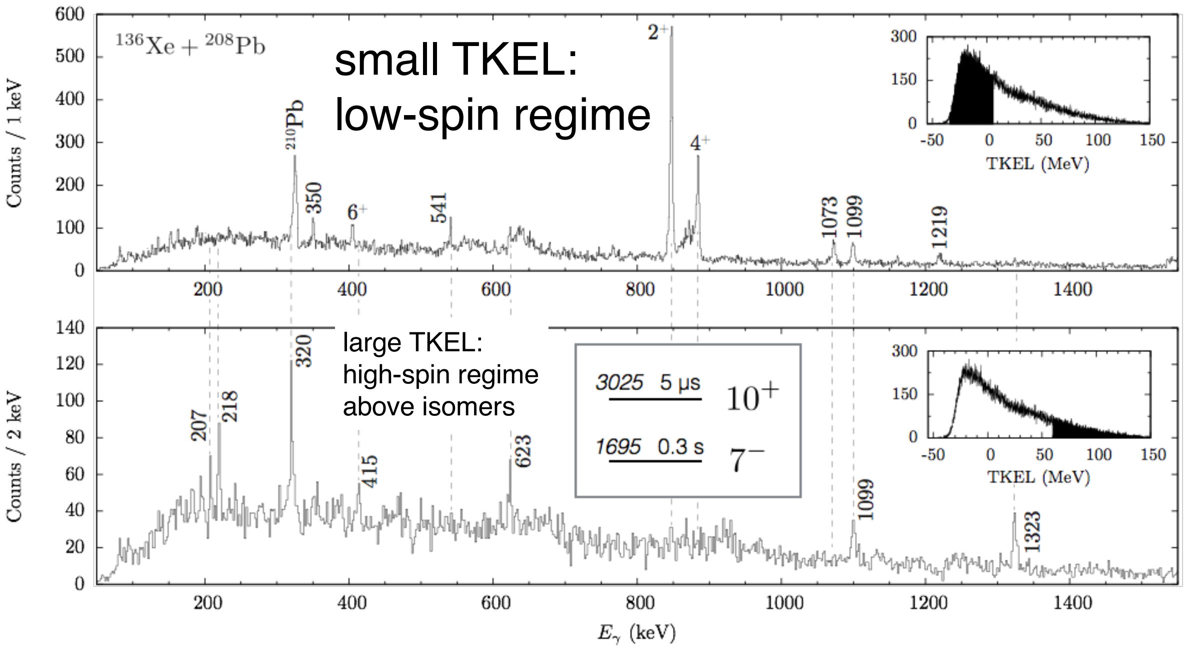
A. Vogt[1], M. Siciliano[2], B. Birkenbach[1], P. Reiter[1], J.J. Valiente-Dobón[2], K. Hadynska-Klek[2], C. Wheldon[3] *et al.*

[1] Institut für Kernphysik Köln, Germany; [2] INFN, Laboratori Nazionali di Legnaro, Italy; [3] SUPA, University of Birmingham, UK

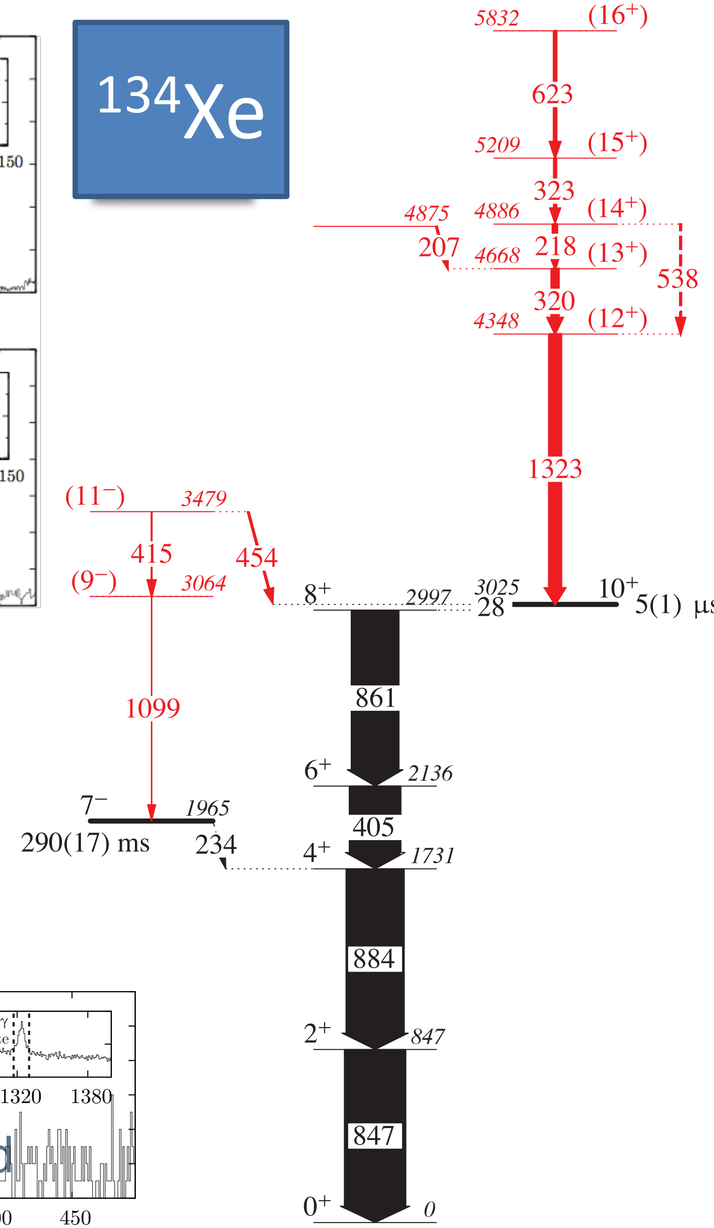


IKP
Universität zu Köln
INFN
AGATA ADVANCED GAMMA TRACKING ARRAY
ENSAR
Gefördert vom Bundesministerium für Bildung und Forschung
bcgs

High-spin spectroscopy of ^{134}Xe



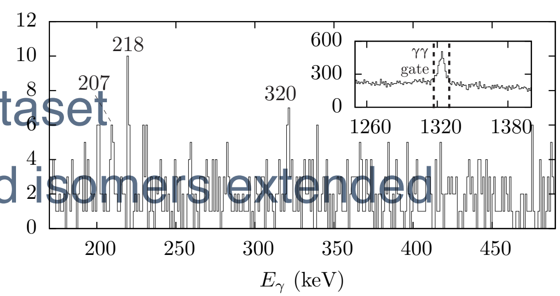
^{134}Xe



- Previously no information on structure beyond the 7$^-$ and 10$^+$ states
- Constrain excitation energies via total kinetic energy loss (TKEL)

dataset

ved isomers extended

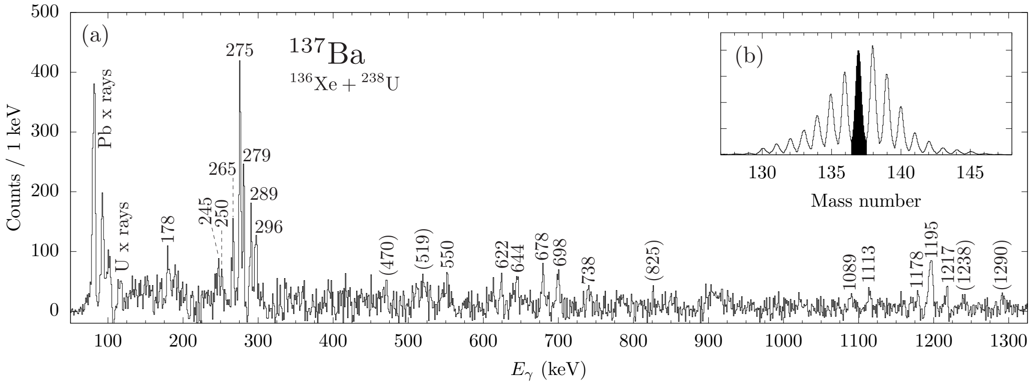


PHYSICAL REVIEW C™

A. Vogt *et al.*
PRC 93, 054325 (2016)

High-spin structure of ^{134}Xe

Isomers and high-spin structures in the N = 81 isotones ^{135}Xe and ^{137}Ba

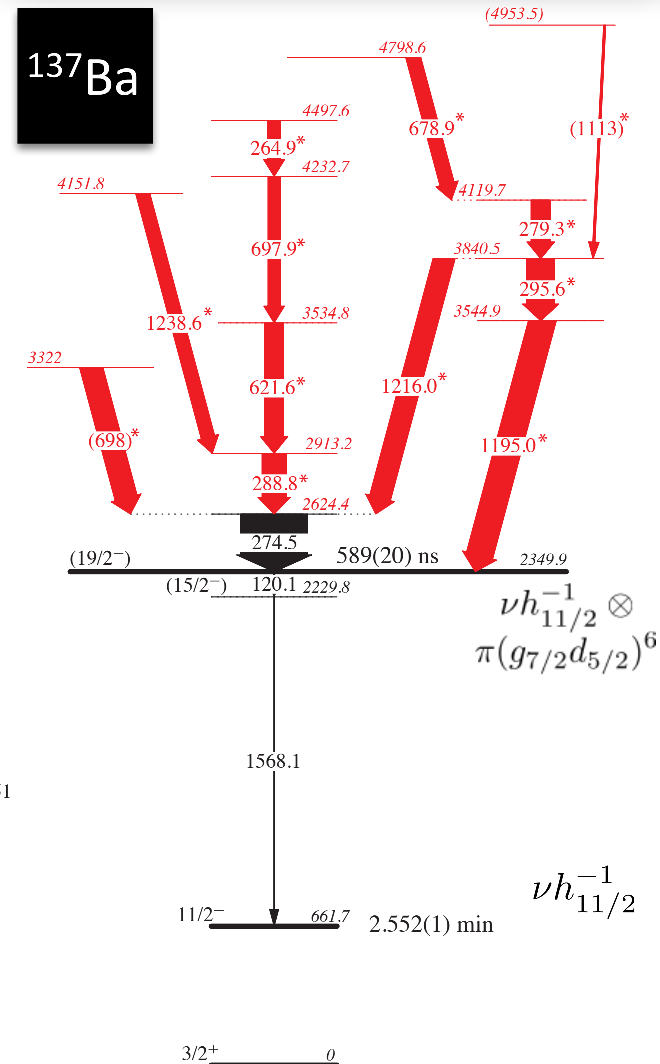


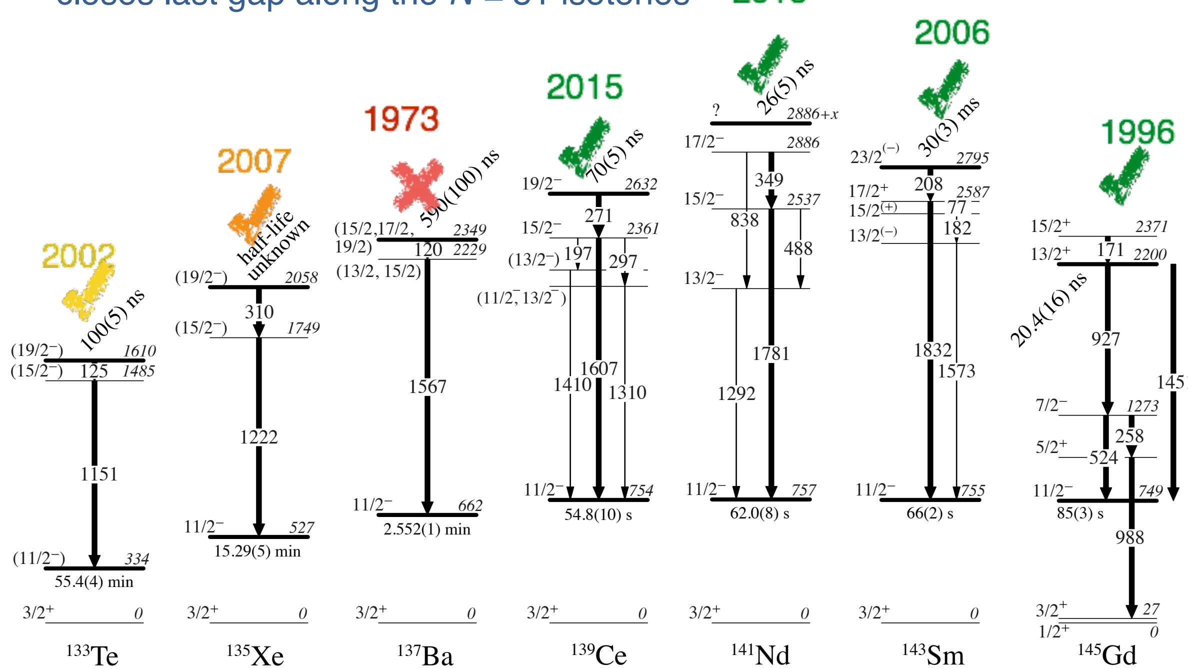
- Up to now: no high-spin data available for ^{137}Ba
- Measurement of isomer half-life in ^{135}Xe closes last gap along the $N = 81$ isotones

PHYSICAL REVIEW C™

A. Vogt *et al.*
PRC 95 024316 (2017)

Isomers and high-spin structures in the N=81 isotones ^{135}Xe and ^{137}Ba



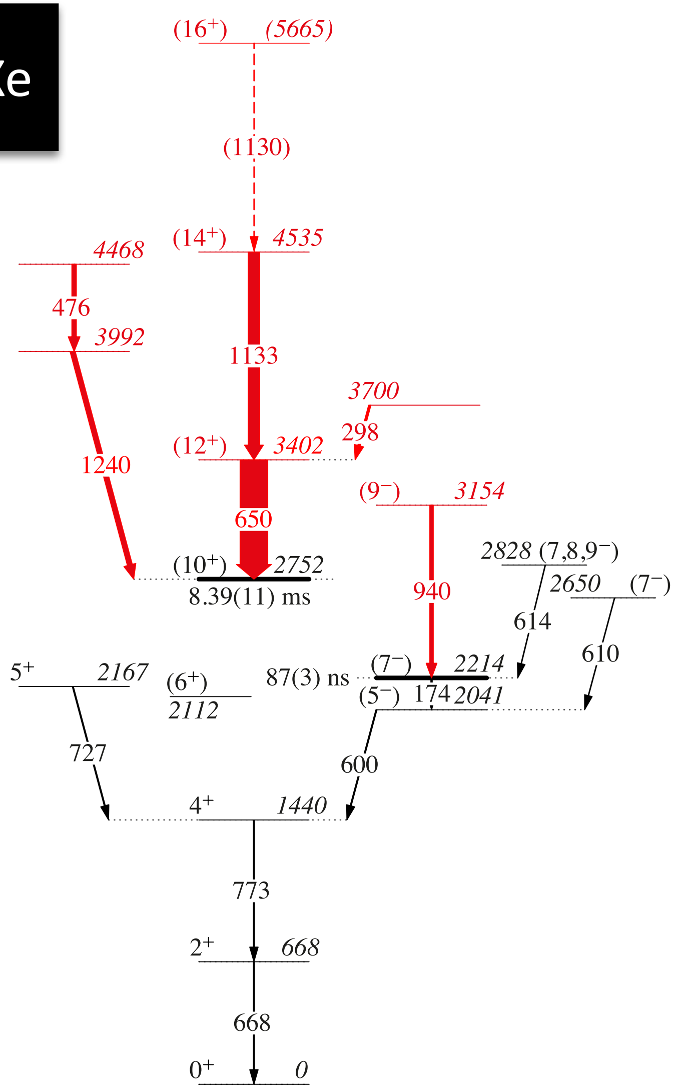


High-spin structures in ^{132}Xe and ^{133}Xe and evidence for isomers along $N = 79$

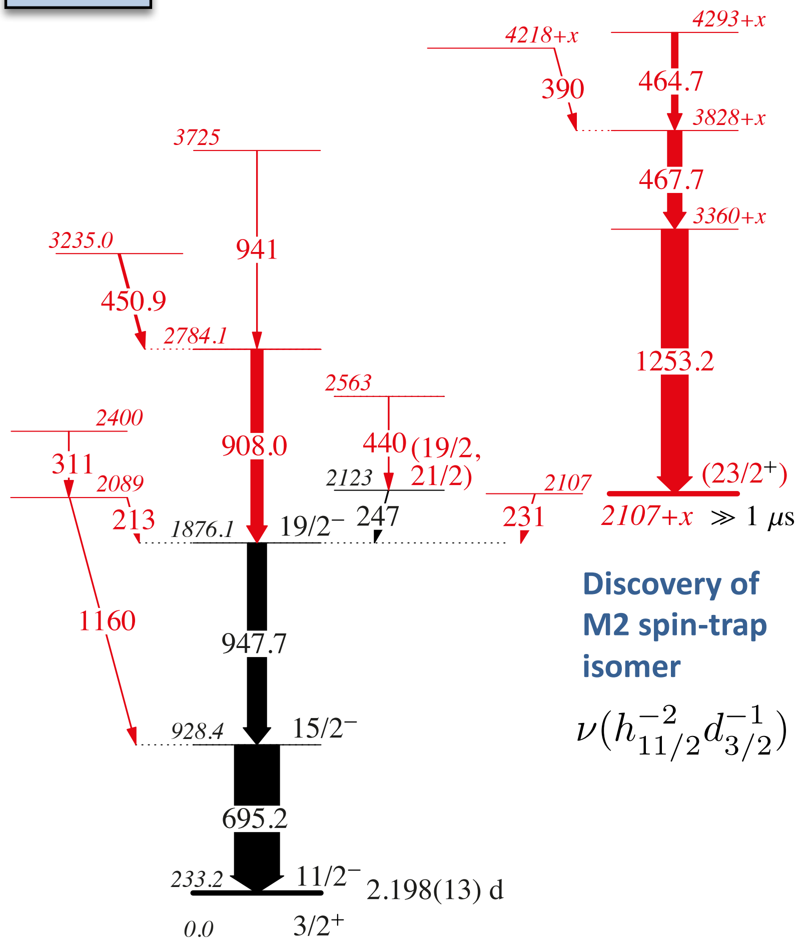
PHYSICAL REVIEW C™

A. Vogt *et al.*
accepted by PRC
High-spin structures in ^{132}Xe and ^{133}Xe and evidence for isomers along the N = 79 isotones

^{132}Xe



^{133}Xe



Discovery of M2 spin-trap isomer

$$\nu(h_{11/2}^{-2} d_{3/2}^{-1})$$

Motivation

- Energy dependence of isospin mixing
- Isospin mixing used to correct the estimation of V_{ud} in the CKM matrix as obtained from superallowed Fermi beta decay
  → unitarity CKM??

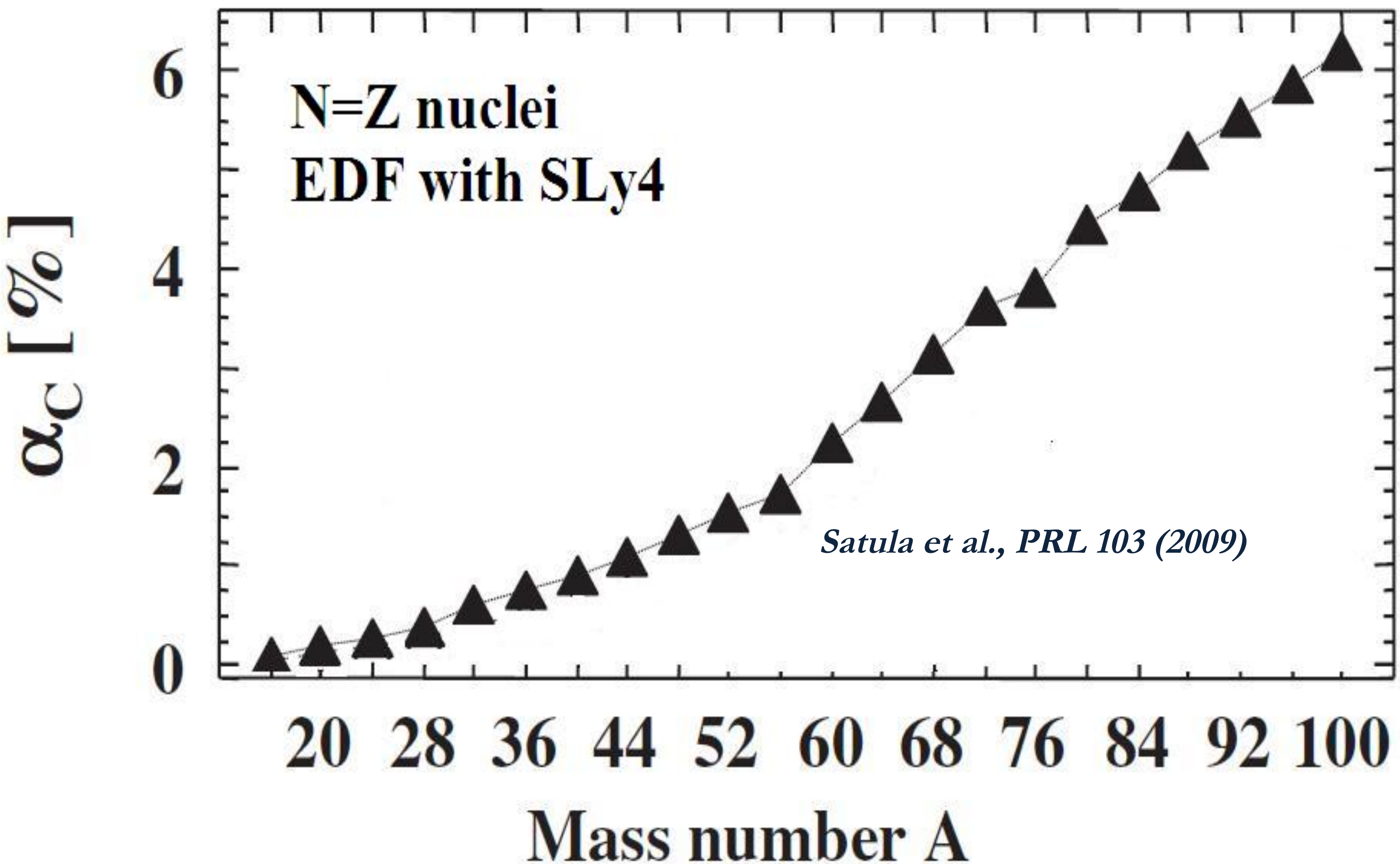
The Isospin Mixing in the ground state

- The presence of the **Coulomb interaction** inside the nucleus causes a **mixing** between states with different isospin
- In a perturbative way the mixing probability in the nuclear ground state is defined as:

$$\alpha^2 = \frac{|\langle I=1|H_c|I=0\rangle|^2}{\Delta E^2} \qquad |A\rangle = \beta|0\rangle + \alpha|1\rangle$$

- Important for N = Z nuclei

The Isospin Mixing in the ground state



Satula et al., PRL 103 (2009)

The Isospin Mixing at T>0

- A **CN** in an excited state has a **finite lifetime τ**
- The lifetime can be so short to not allow a complete mixing
- At high excitation energy (and thus at short lifetime) the isospin symmetry is **restored**
- Lifetime implies a **dynamical behavior** of the isospin mixing phenomenon

What to observe

For the $E1$ transitions the giant dipole resonance (GDR), where the maximum $E1$ strength is concentrated, is ideal for searching for small effects in the breaking of the associated selection rule [8–10]. For $N = Z$ nuclei with medium mass, being not stable, the approach that can be used is to form, via fusion reactions, compound nuclei (CN) with $N = Z$ at finite temperature (T) and then deduce isospin mixing at $T = 0$ using the model of [11] connecting this quantity from $T = 0$ to finite T.

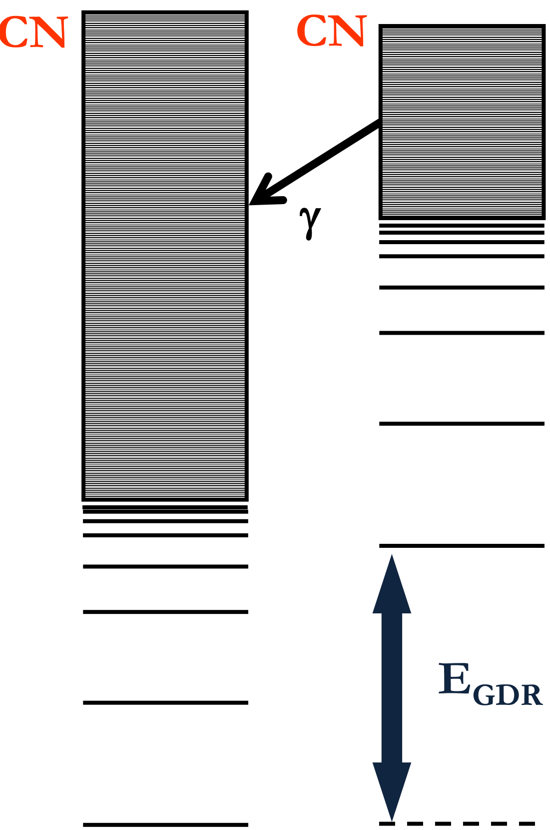
The breaking of isospin symmetry can be observed through decays which would be inhibited by selection rules.

The Isospin Mixing

- In N=Z nuclei I=0
- In N=Z nuclei the **Electric Dipole transitions** in long-wavelength limit are forbidden in states with the same isospin.

$$I_{fin} = I_{in} \pm 1$$

GDR at Temperature > 0

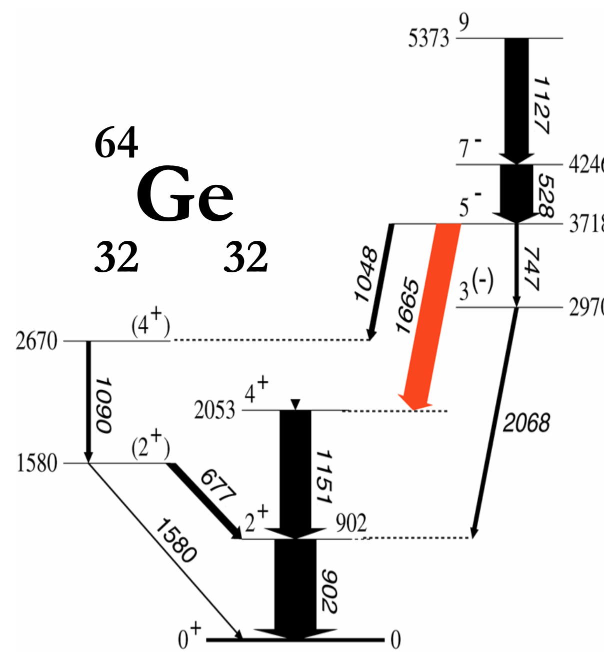


Selection rule:
E1 decays correspond to change of isospin

The **mixing** increases the γ decay yield

The observed **E1 strength** is a signature of the mixing

Temperature= 0



E. Farnea et al. Phys. Lett. (2002)

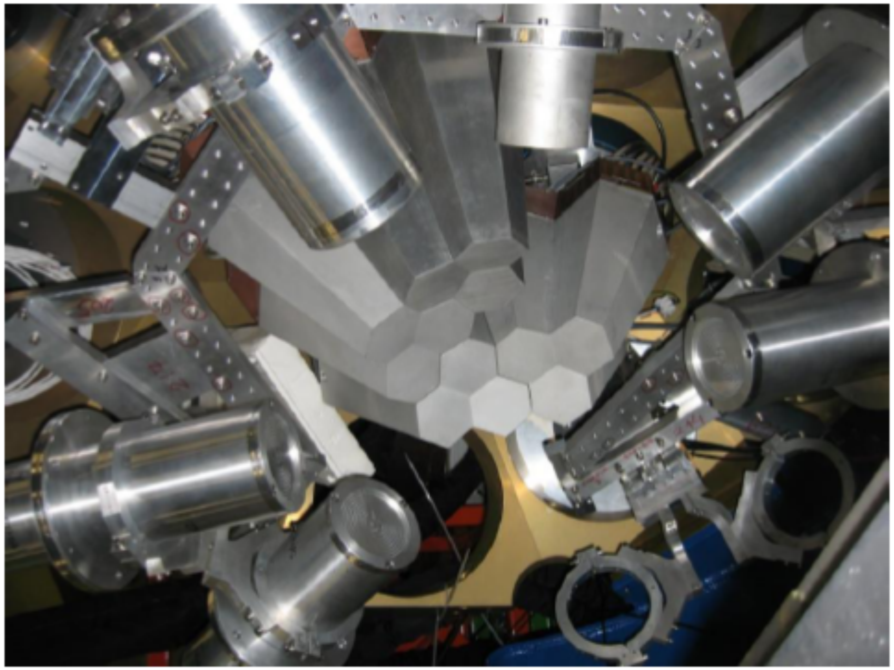
α^2=2.50(+1.0-0.7)%

The reactions

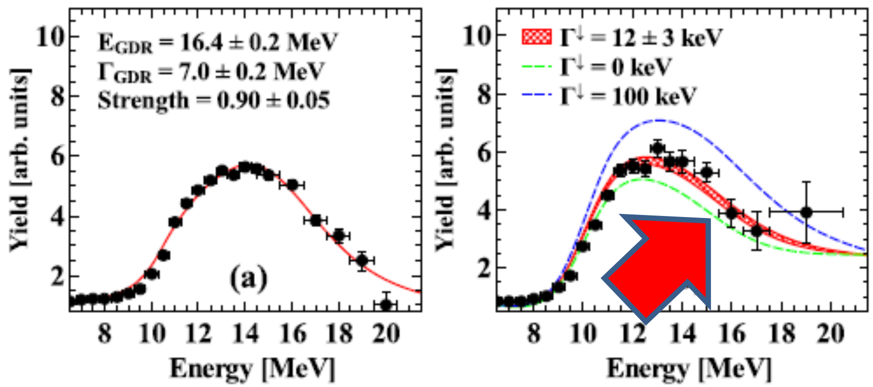
- $^{40}Ca + ^{40}Ca$ at E_{beam} = 136 MeV was used to form the compound nucleus in the isospin I=0 channel
- $^{37}Cl + ^{44}Ca$ at E_{beam} = 95 MeV was used as the reference reaction.

AGATA – HECTOR^{+} array @ LNL

4 AGATA Clusters (12 capsules)
6 $LaBr_3$:Ce (3.5” x 8”)
1 $LaBr_3$:Ce (3 x 3”)



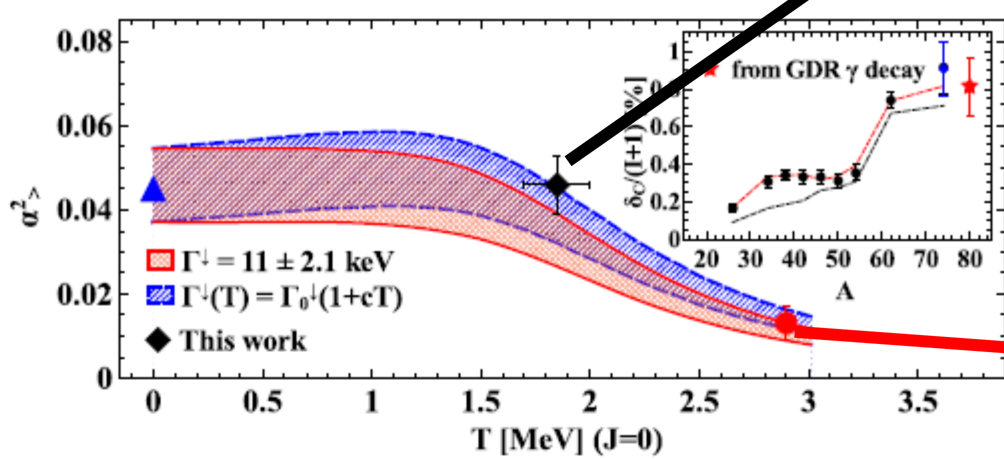
Results



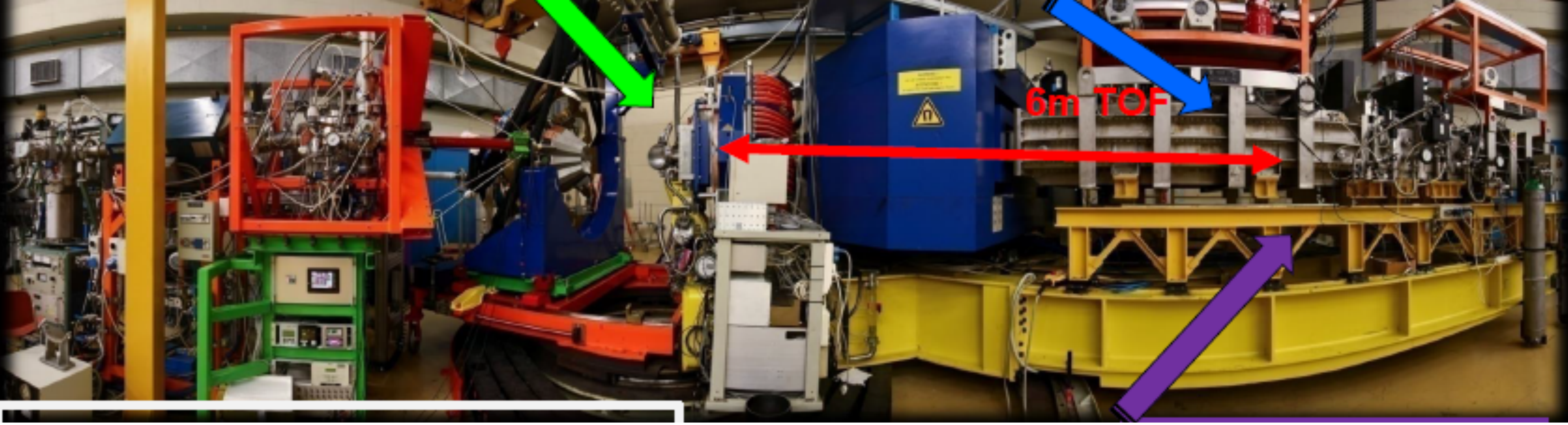
Enhancement of E1 with respect to model → due to isospin mixing → we can measure it!

FIG. 3 (color online). Linearized measured and calculated γ-ray spectra for ^{37}Cl + ^{44}Ca (a) and for ^{40}Ca + ^{40}Ca (b) in the GDR region. In (b) the statistical model calculations are shown corresponding to different values of the Coulomb spreading width: $\Gamma_{>}^{\downarrow} = 12$ keV (red line), for no mixing $\Gamma_{>}^{\downarrow} = 0$ keV (green dashed line), and for full mixing $\Gamma_{>}^{\downarrow} = 100$ keV (blue dashed line).

This work



A. Corsi



$^{82}Se + ^{198}Pt$

PHYSICAL REVIEW C **95**, 064321 (2017)

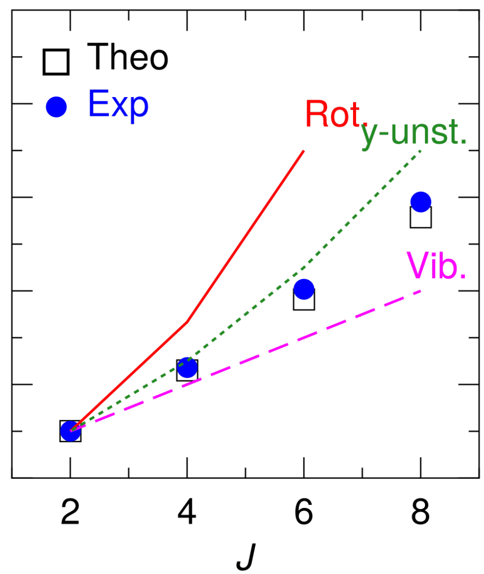
In-beam γ-ray spectroscopy of the neutron-rich platinum isotope ^{200}Pt toward the $N = 126$ shell gap

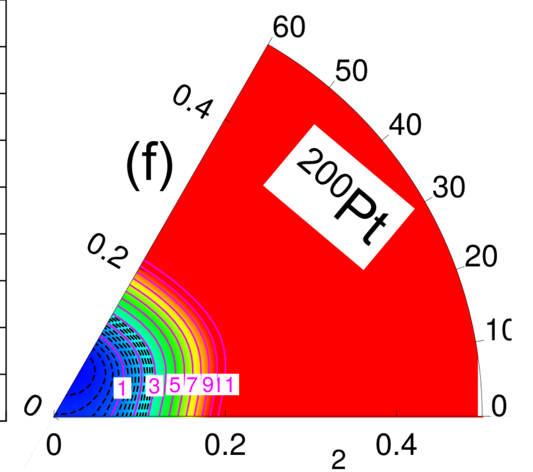
P. R. John,[1,2,*] J. J. Valiente-Dobón,[3] D. Mengoni,[1,2] V. Modamio,[3,†] S. Lunardi,[1,2] D. Bazzacco,[2] A. Gadea,[4] C. Wheldon,[5] T. R. Rodríguez,[6,7] T. Alexander,[8] G. de Angelis,[3] N. Ashwood,[5] M. Barr,[5] G. Benzoni,[9,10] B. Birkenbach,[11] P. G. Bizzeti,[12,13] A. M. Bizzeti-Sona,[12,13] S. Bottoni,[9,10,‡] M. Bowry,[8] A. Bracco,[9,10] F. Browne,[14] M. Bunce,[8] F. Camera,[9,10] L. Corradi,[3] F. C. L. Crespi,[9,10] B. Melon,[12,13] E. Farnea,[2] E. Fioretto,[3] A. Gottardo,[1,3,§] L. Grente,[15] H. Hess,[11] Tz. Kokalova,[5] W. Korten,[15] A. Kuşoğlu,[16,17] S. Lenzi,[1,2] S. Leoni,[9,10] J. Ljungvall,[18] R. Menegazzo,[1,2] C. Michelagnoli,[1,2,‖] T. Mijatović,[19] G. Montagnoli,[1,2] D. Montanari,[1,2,¶] D. R. Napoli,[3] Zs. Podolyák,[8] G. Pollarolo,[20,21] F. Recchia,[1,2] P. Reiter,[11] O. J. Roberts,[14,**] E. Şahin,[3,†] M.-D. Salsac,[15] F. Scarlassara,[1,2] M. Sferrazza,[22] P.-A. Söderström,[23,††] A. M. Stefanini,[3] S. Szilner,[18] C. A. Ur,[2,‡‡] A. Vogt,[11] and J. Walshe[5]

In-beam γ-ray spectroscopy of the neutron-rich ^{200}Pt platinum isotope

- Data from the ^{196}Os Experiment
  John et. al PRC 90, 021301(R) (2014)
- Extended ground state band
- Compared to SCCM calculations
- ^{200}Pt marks the transition from the γ-unstable behaviour of lighter Pt

Extended yrast band

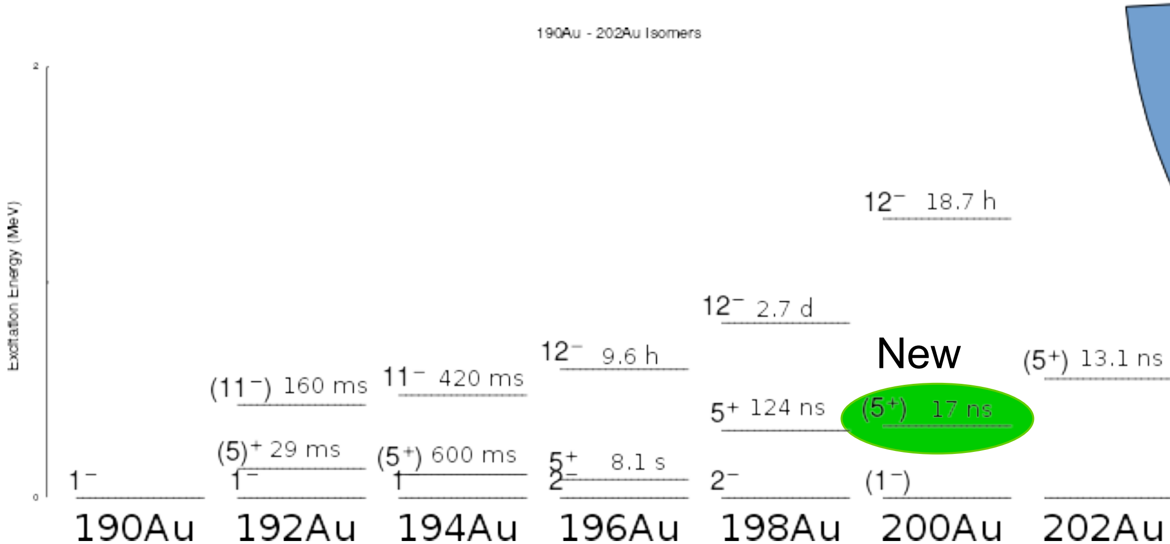


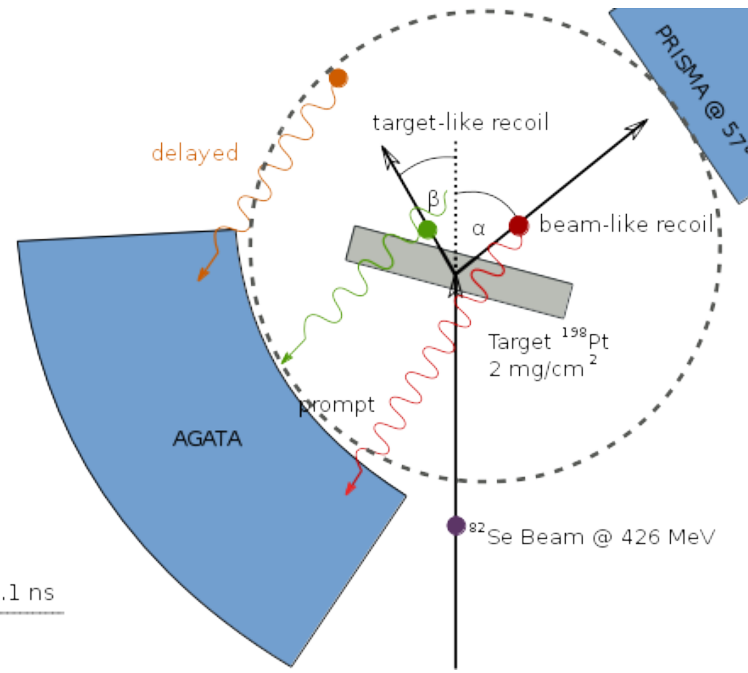


P. R. John et al. Phys. Rev. C 95, 064321 (2017)

Isomeric States in the neutron-rich Au isotopes

- Delayed AGATA spectra
- New isomeric state in ^{200}Au found
- Suppose to be the 5^{+} isomer
- Publication in preparation





The publications of the LNL campaign

- *Isomers and high-spin structures in the N=81 isotones ^{135}Xe and ^{137}Ba* PRC A. Vogt
- *Experimental study of the isovector giant dipole resonance in ^{80}Zr and ^{81}Rb* PRC S.Ceruti
- ***Highly-deformed and triaxial states in ^{42}Ca* PRL K. Hadyńska-Klek**
- *Pair neutron transfer in ^{60}Ni + ^{116}Sn probed via gamma-particle coincidences* PRC D. Montanari
- *Study of the pygmy dipole resonance in ^{140}Ce via inelastic scattering of ^{17}O* PRC M. Krzysiek
- *Transition probabilities in neutron-rich ^{84,86}Se* PRC J. Litzinger
- *High-spin structure of ^{134}Xe* PRC A. Vogt
- *Population of the 2+ms mixed-symmetry state of ^{140}Ba by the α-transfer reaction* PRC C. Stahl
- *Spectroscopy of the neutron-rich actinide nucleus ^{240}U following multinucleon-transfer reactions* PRC B. Birkenbach
- *Light and heavy transfer products in ^{136}Xe + ^{238}U multinucleon transfer reactions* PRC A. Vogt, B. Birkenbach
- ***Isospin mixing in ^{80}Zr: from finite to zero temperature* PRL S. Ceruti, F. Camera**
- *Multitude of 2^+ discrete states in ^{124}Sn observed via the (^{17}O, ^{17}O ' γ) reaction: Evidence for pygmy quadrupole states* PRC L. Pellegri
- *Shell evolution beyond N=40: ^{69,71,73}Cu* PRC E. Sahin
- *Low-lying E1 and high-lying E2 states in ^{90}Zr populated via the (^{17}O, ^{17}O'γ) reaction* PRC F.C.L. Crespi
- ***Pygmy Dipole Resonance in ^{124}Sn populated by inelastic scattering of ^{17}O* PLB L. Pellegri**
- ***Isospin character of low-lying pygmy states in ^{208}Pb via inelastic scattering of ^{17}O ions* PRL F.C.L. Crespi**
- *Shape evolution in the neutron-rich Osmium isotopes: prompt gamma-ray spectroscopy of ^{196}Os* PRC P.R. John
- *Lifetime measurements in neutron-rich ^{63,65}Co isotopes using the AGATA demonstrator* PRC V. Modamio
- *Global properties of K-hindrance probed by the γ-decay of the warm rotating ^{174}W nucleus* PRC V. Vandone
- *Collective nature of low-lying excitations in ^{70,72,74}Zn from lifetime measurements using the AGATA Demonstrator* PRC C. Louchart
- *Towards the Determination of Superdeformation in ^{42}Ca* APPB K. Hadyńska-Klek
- *High-spin Structure in ^{40}K* PRC P.-A. Söderström

18 Phys. Rev. C + 3 Phys. Rev. Lett. + 1 Phys. Lett. B

Concluding remarks:

- Productive in publications – it takes a great effort and some time on a new device.
  - After 6 years not all the results are out, analysis is still ongoing for some experiments.
- Importance of the broad range of ancillary detectors for stable beams operations.
- AGATA: A successful European collaboration.