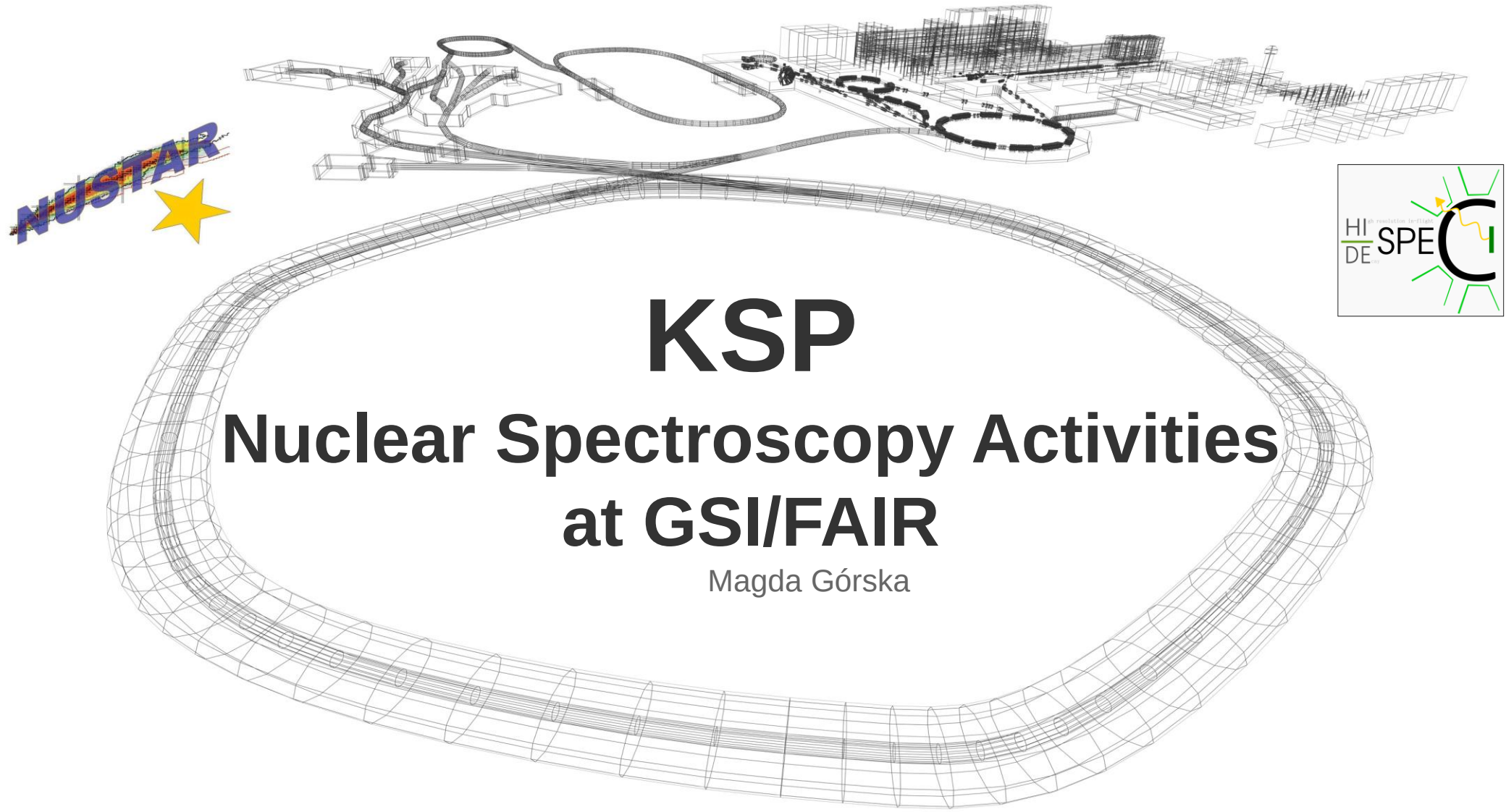


KSP

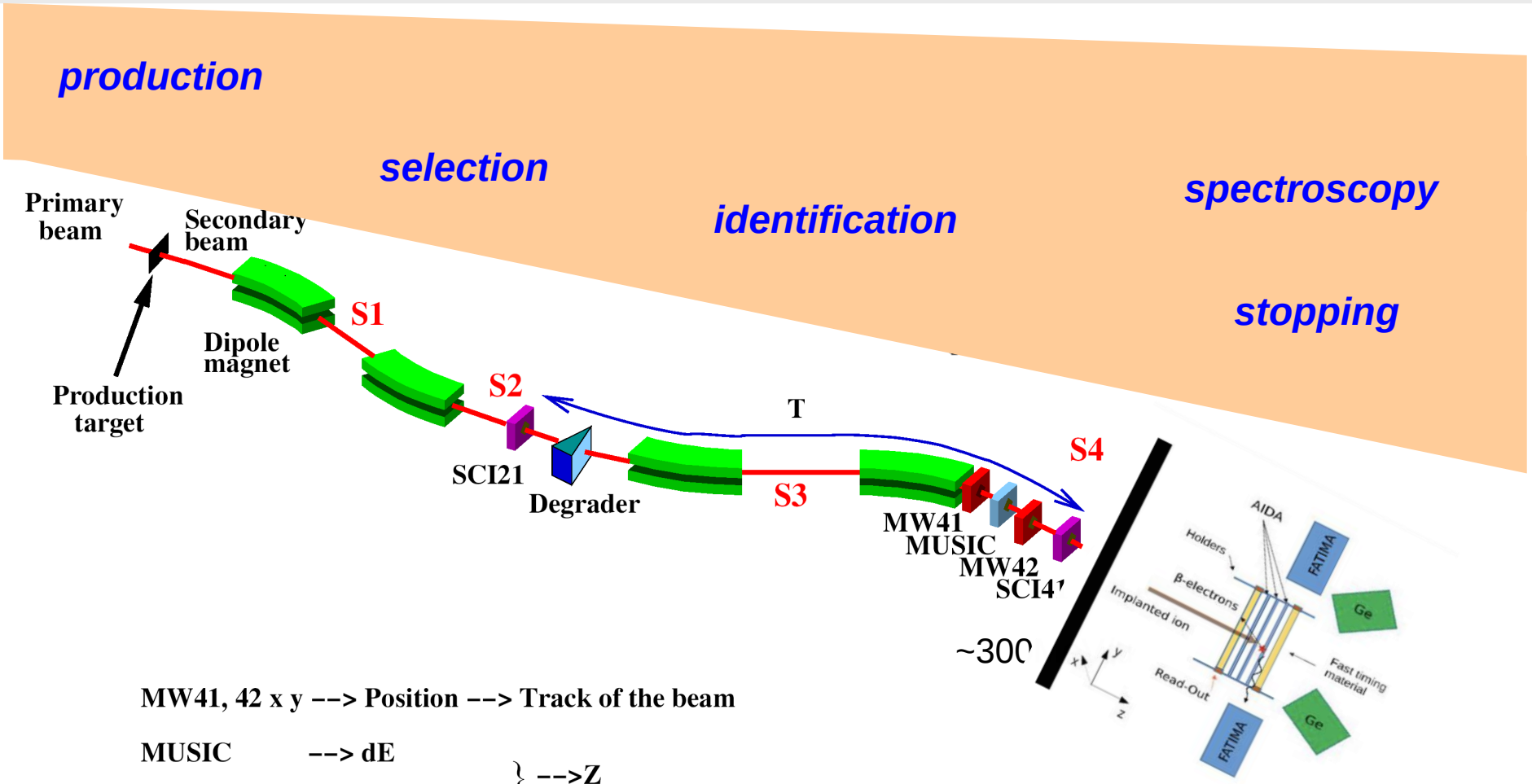
Nuclear Spectroscopy Activities at GSI/FAIR

Magda Górska

Scientific Goals and tools

- Spectroscopic studies of KSP attracts an international community and initiated both in-beam (HISPEC) and stopped ions (DESPEC) collaborations.
- **Several dedicated spectrometers** organized in campaigns e.g. AGATA, DEGAS, FATIMA, DTAS, PARIS…
- Evolution of the shell structure and exotic nuclear shapes in uncharted nuclear territory
- Spectroscopic information for the nucleosynthesis of heavy nuclei
- Comprehensive decay information from identified key nuclei at secondary beam yields as low as one ion per hour
- Primary focus on **GSI-FAIR uniqueness around N~126** nuclei, while providing **competitive data** on key nuclei in lighter regions: around ^{100}Sn and ^{132}Sn, rare earth nuclei, …

DESPEC: Experiments with Stopped Beams 2020-2025



MW41, 42 x y --> Position --> Track of the beam

MUSIC --> dE

SCI 21, 41 --> TOF --> β } --> Z

D. Magnet --> B ρ } --> A/Q

$$\frac{A}{Q} = \frac{B \rho e}{\beta \gamma c u}$$

SETUPS for 2020-2025

A.K. Mistry et al., NIM A 1033 (2022) 166662

S. Saha et al. NIMA 975, 164196 (2020)

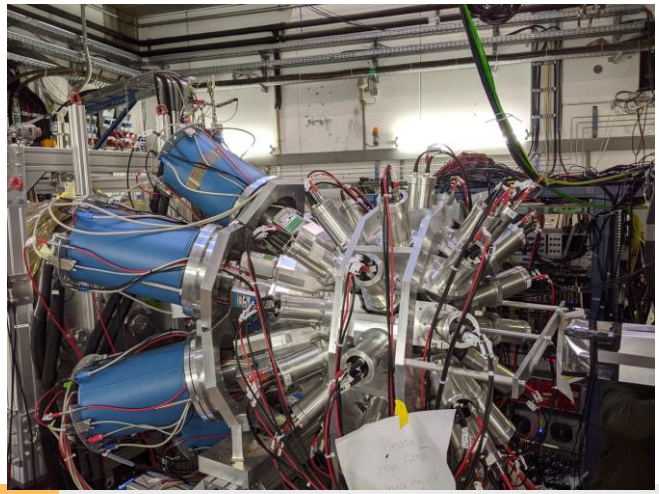
DESPEC sensitive to exotic nuclei at the limit of existence to extract nuclear structure information

- lifetime measurement spanning 13 orders of magnitude (10ps-100s)
- different decay modes α,β,γ and n

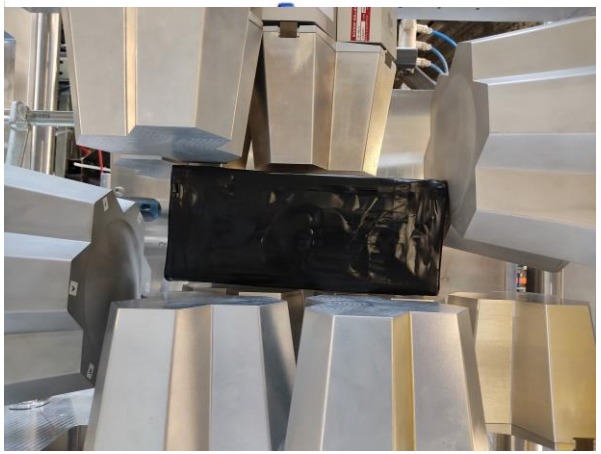
AIDA

surrounded with:

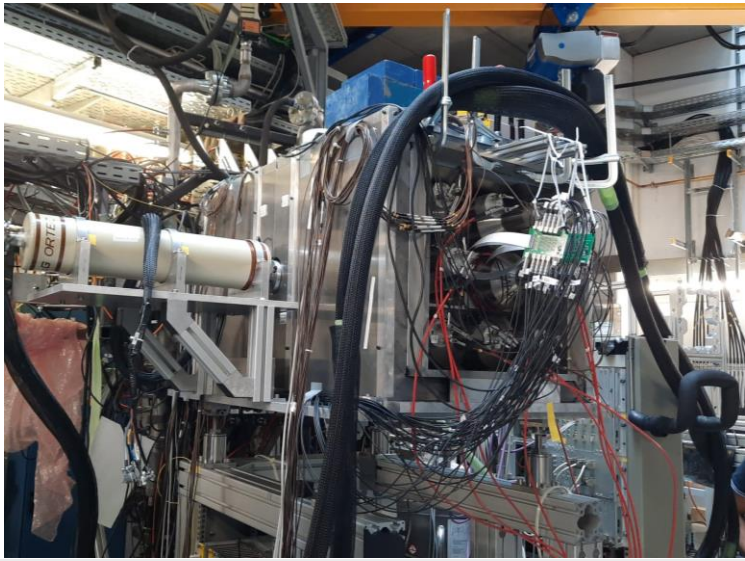
FAST TIMING: 36 det. FATIMA
eff. 2.9% at 1 MeV
6 GTC DEGAS or GALILEO
eff. 3% at 1 MeV



HIGH RESOLUTION:
28 DEGAS eff. 18% at 1 MeV

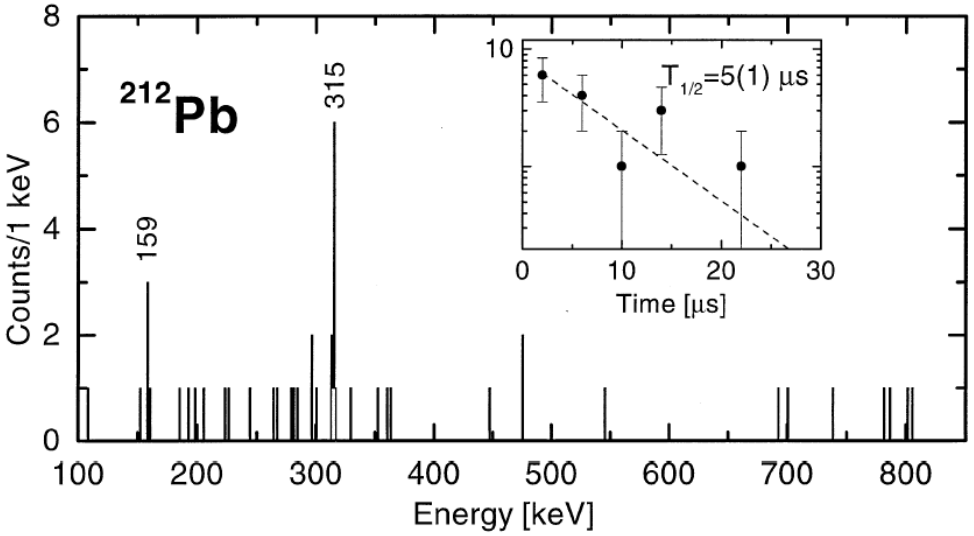


HIGH EFFICIENCY:DTAS



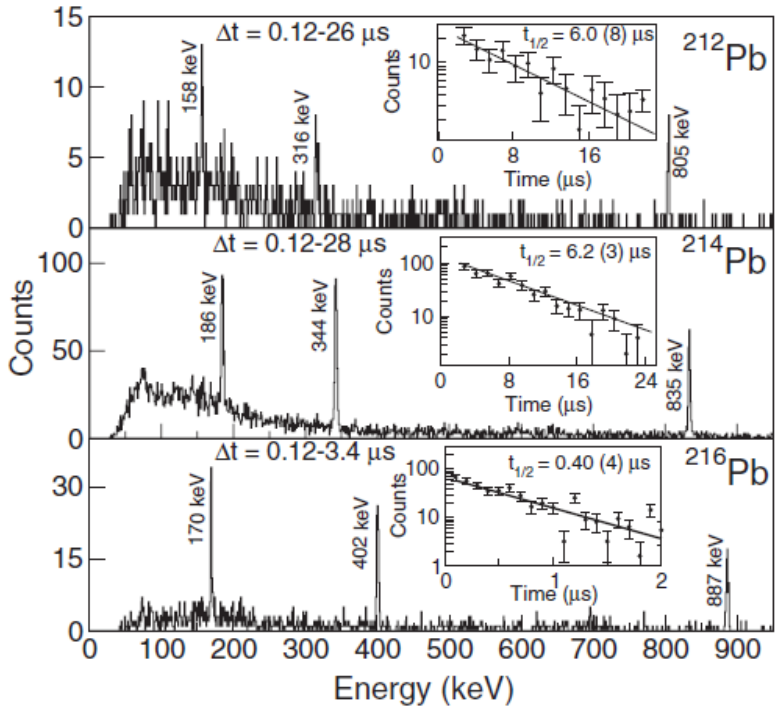
DESPEC: very sensitive!

370 implanted ^{212}Pb ions!



M. Pfützner et al., Phys. Lett. B 444 (1998) 32.

RISING setup 15% Ge det. array efficiency

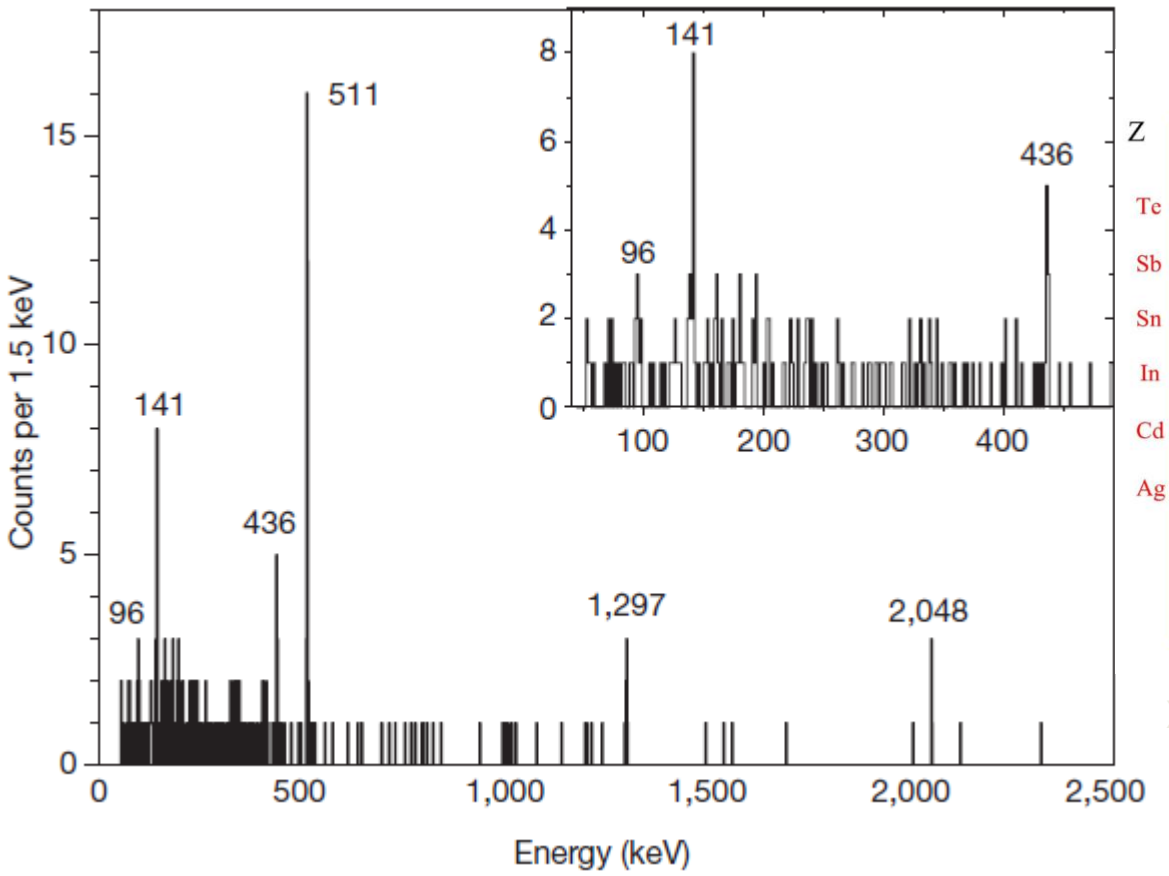


A. Gottardo et al., PRL 109, 162502 (2012)

Perfectly suited for secondary beam cocktail check

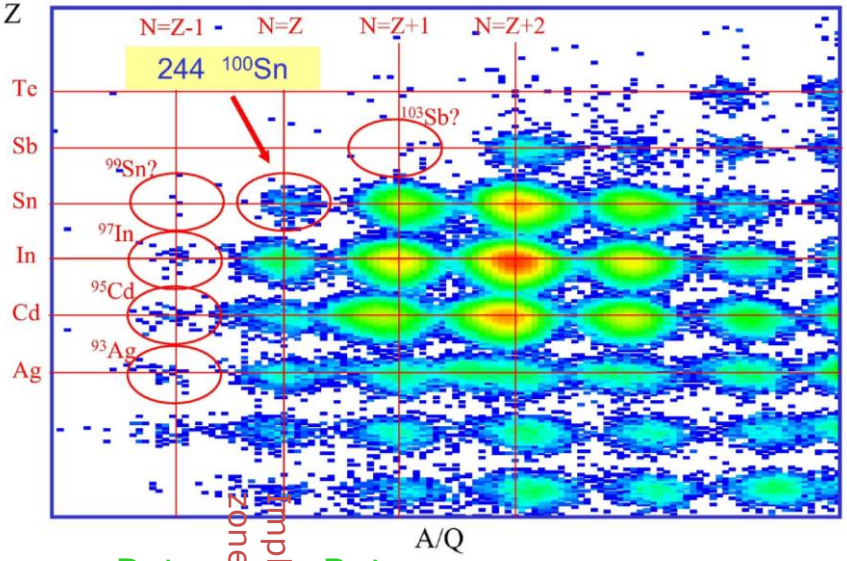
DESPEC sensitivity: β-decay of ^{100}Sn

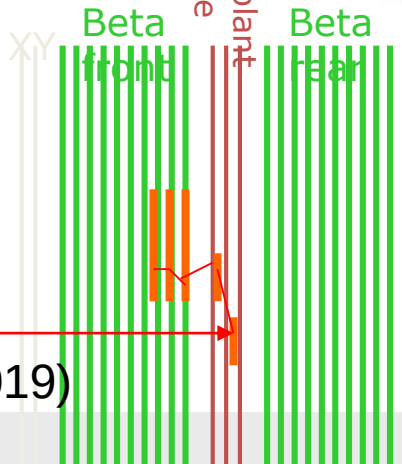
C. B. Hinke et al, Nature 486 (2012) 341



<1ion/hour!

^{100}Sn setting (full statistics, 15 days)





RIKEN with 10x statistics:
All gamma rays confirmed and no new found!
D. Lubos *et al.* Phys. Rev. Lett. 122, 222502 (June 2019)

Hispec-Despec experimental program for FAIR Phae-0:

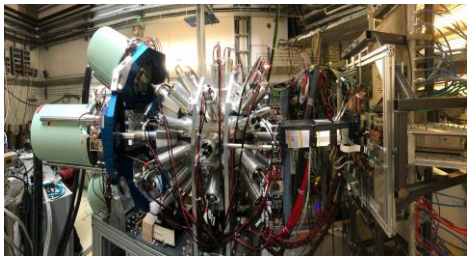
Phase-0 2020-2022

Restarted experimental program @ GSI thanks to improved performances of developed detectors

➔ DESPEC campaign on isomeric and β decays

➔ Levels lifetimes; decay half-lives; new spectroscopy

➔ Z=N=50; Rare earths



Phase-0 2024-2025

➔ Parasitic runs to test future DESPEC configurations and first HISPEC experiments

➔ contributing to a FRS experiment with the DESPEC setup

Phase-0 2026-

Decay and isomer spectroscopy around N=126: multifaceted approach

A~195 r-process abundance peak fed by **nuclei around N=126**

- **Half-lifes (and P_n)** values
- Role of **First Forbidden β-decay transitions**
- Access to **GT strength** with Total Absorption Spectroscopy

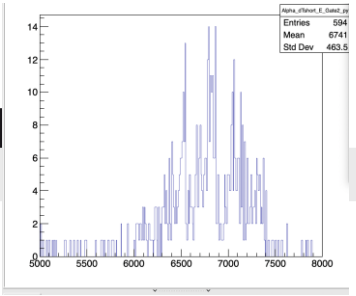
➔ Measurements possible down to **nb level**

Prerequisite:

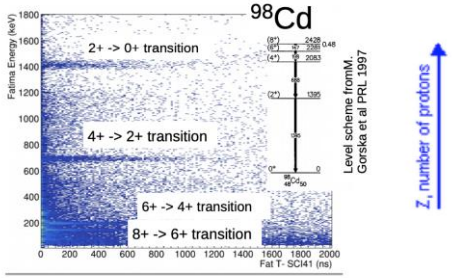
- steadily increasing beam intensity
- place for detectors (incl. neutron detector, etc)
- funds for detector maintenance as time stretches (partly collaboration)
- maintained continuation of the local expertise

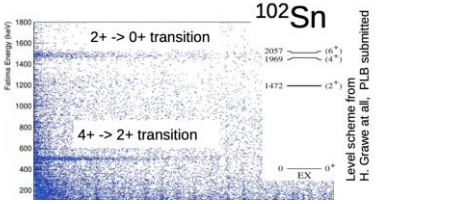
Experimental campaigns in 2020-2021

α decay of 218Rn, calibration nucleus

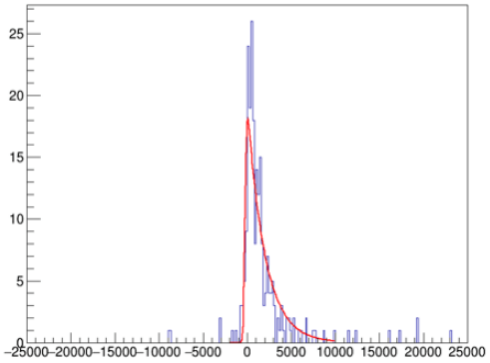


S496 Core-breaking in the most neutron-deficient Tin isotopes (in preparation)





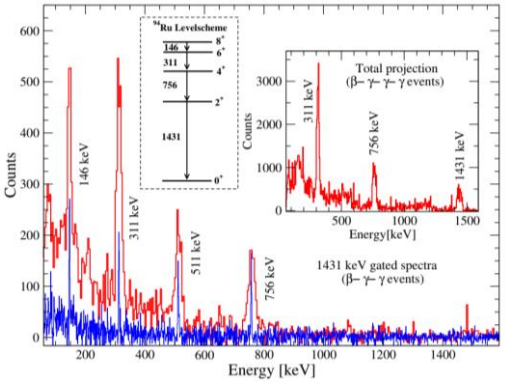
100Cd 6 delay



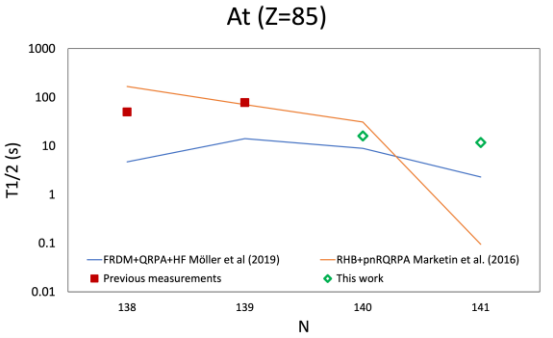
$T_{(1/2)}(6^+)^{exp} = 1.4(1)$ ns

$B(E2, 6^+ \rightarrow 4^+) = 170\ ^{+23}_{-12}\ e^2\ fm^4$

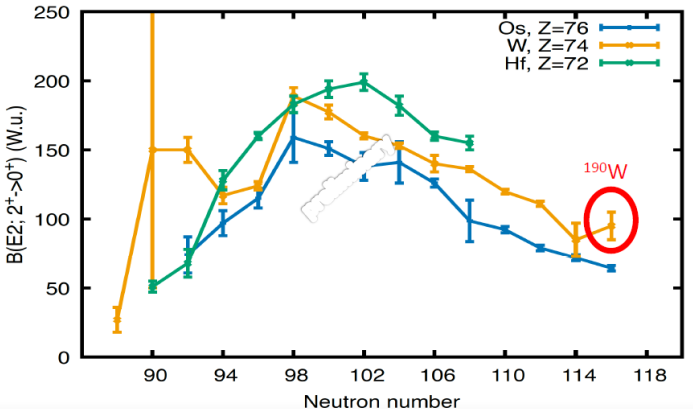
S480: Seniority Transitions and EM Transition Rates below 100Sn

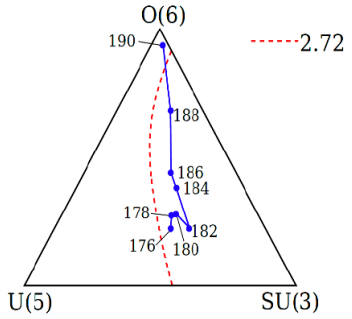


S460: Investigation the south-east frontier of the A~225 island of octupole deformation



S452 Shape Evolution at A~190 (in preparation)

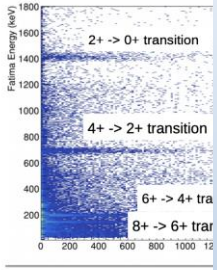


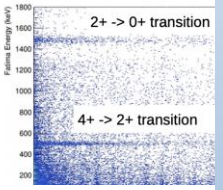


B(E: 2+-> 0+) = 95(10)W.u.

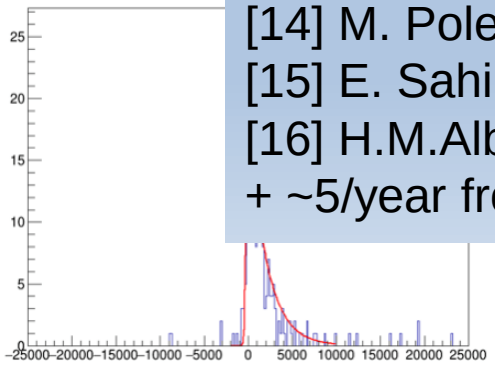
Experimental campaigns in 2020-2021

S496 Core-b
the most neu
deficient Tin
preparation)





100C

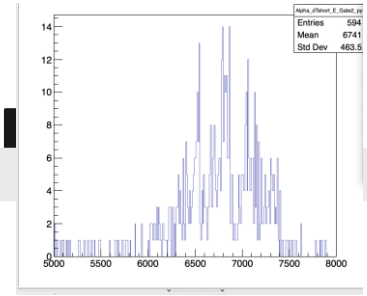


$T_{(1/2)}(6^+)^{exp} = 1.4(1)$ ns

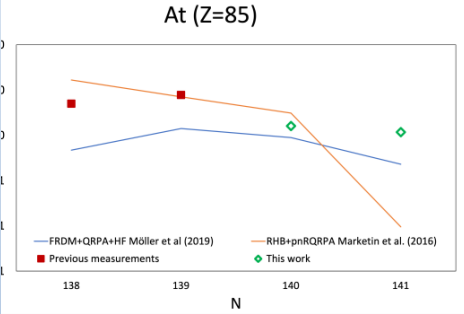
$B(E2, 6^+ \rightarrow 4^+) = 170\ ^{+23}_{-12}\ e^2\ fm^4$

[1] Mistry A K et al., 2022 *Nucl. Inst. Meth.* **A 1033**, 166662.
[2] Jazrawi S et al., 2022 *Rad. Phys. Chem.* 200, 112234.
[3] Polettini M et al., 2021 *Il Nuovo Cimento* 44, C 67.
[4] Das B et al., 2022 *Phys. Rev.* C **105**, L031304.
[5] Banerjee A et al., 2022 *Nucl. Inst. Meth.* **A 1028**, 166357.
[6] Gorska M, 2022 *Physics* ***4*(1)**, 364.
[7] Das B et al., submitted
[8] Gorska M et al., submitted
[9] Benzoni G et al., submitted
[10] Polettini M et a., submitted
[11] Yaneva A, S. Jazrawi et al., submitted
[12] Yaneva A, S. Jazrawi et al., in preparation
[13] Zhang G, Mengoni D et al., in preparation
[14] M. Polettini, G, Benzoni et al., in preparation
[15] E. Sahin et al., in preparation
[16] H.M.Albers and A. Montalbano, in preparation
+ ~5/year from other facilities

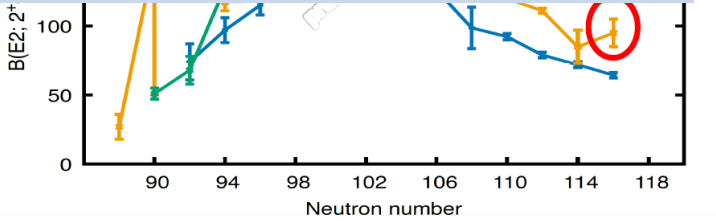
α decay of 218Rn, calibration nucleus



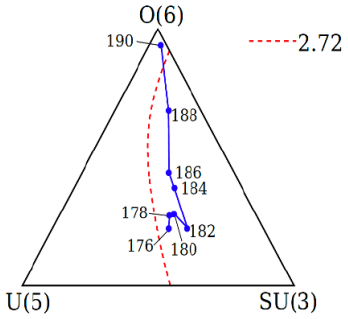
estigation the south-east
f the A~225 island of
deformation



n preparation)



$B(E: 2^+ \rightarrow 0^+) = 95(10)$W.u.

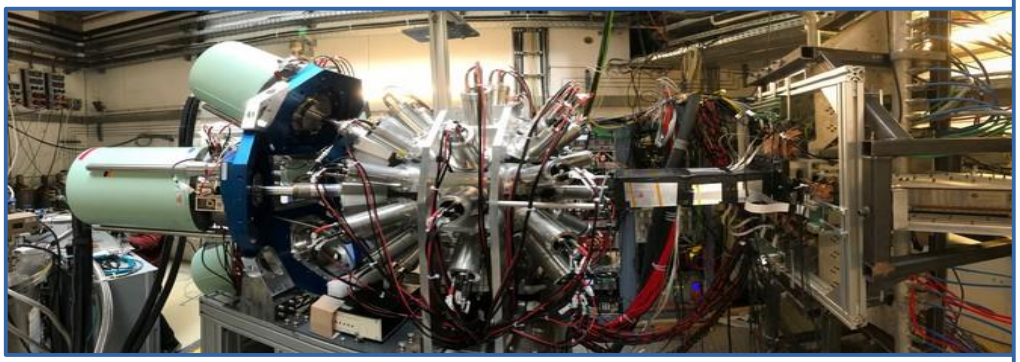


DESPEC plans for the near future: FATIMA

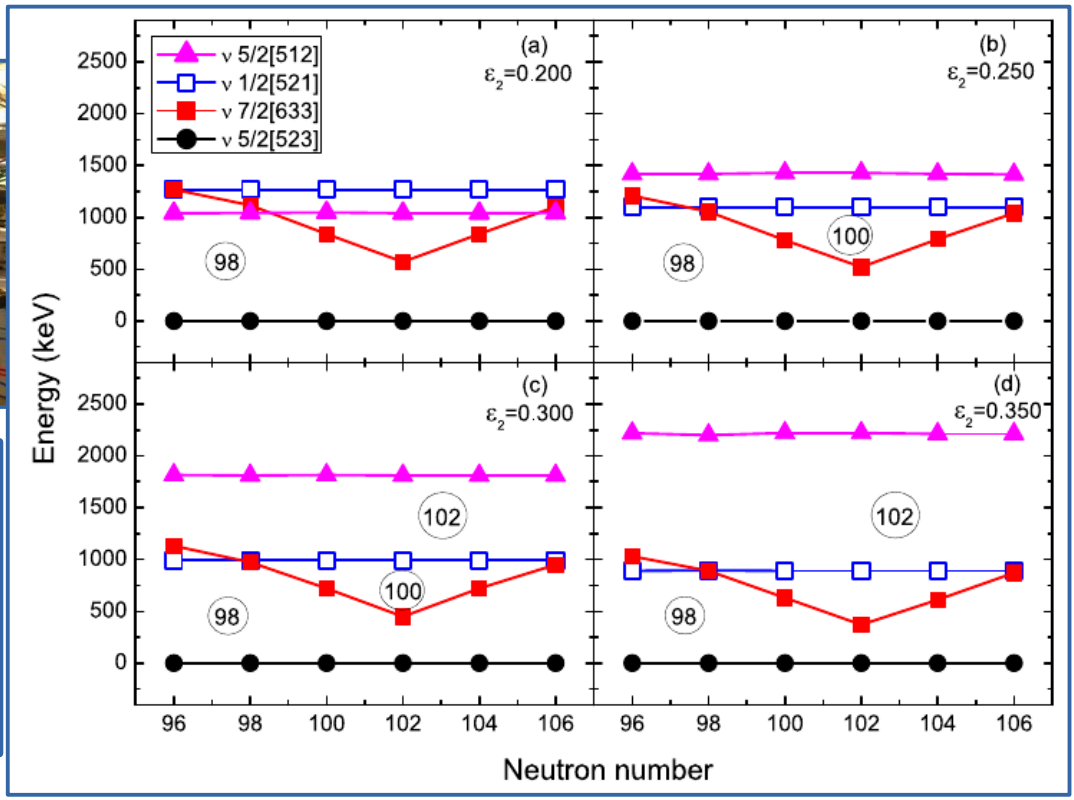
Structure of neutron-rich, rare-earth nuclei far from stability

H.M. Albers (GSI), T. Grahn (Jyskl), C.M. Petrache(Paris) and V. Werner(TUD)

New approach in FAIR Phase-0: **Beam of 170Er increasing the production cross section**



- Location and size of deformed shell gaps ***highly-dependent*** *on N and deformation parameter*
- Effect of v7/2[633] most apparent at N=98-104



Decay properties of 160,162Eu at ANL → deformed shell gap at N=98 D.J. Hartley *et al.*, PRL **120**, 182502 (2018)

DEGAS (84Mo isomer search) + test experiments: FIMP, g-DEGAS

HISPEC plans for the near future: Slow Down Beams test, LISA test (ERC grant)

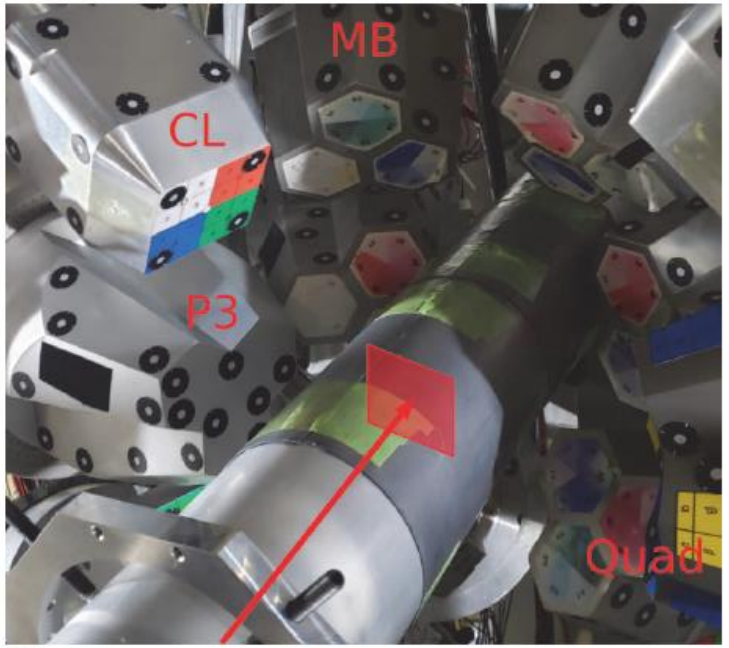
In-beam experiments at RIBF (HISPEC type) 8 experiments campaign

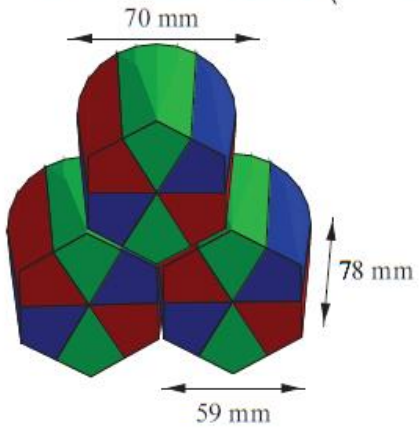
- Organizing international collaboration
- and available position sensitive Ge detectors

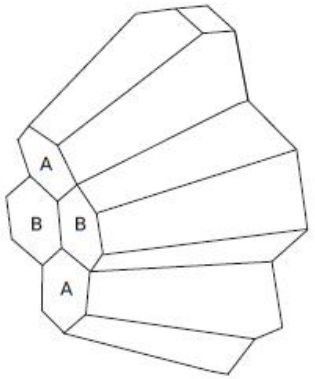
- hikari 光 means “light”
- Wako-shi (city where RIBF is) 和光市

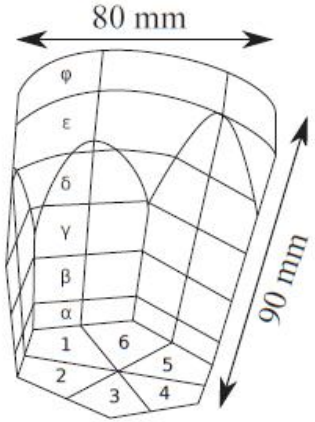
international effort:

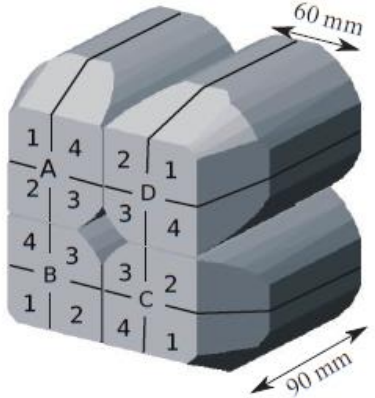
- 6 Miniball triple-cluster from Europe
- RCNP quad (GRETA-type, Japan)
- LBNL triple (GRETA-type, USA)
- 4 Super-Clovers from IBS (Korea)
- 4 Clovers from IMP Lanzhou (China)
- GRETA-type electronics and DAQ (RCNP, ANL, LBNL, U Tokyo)
- Miniball frame (U Köln, Germany)







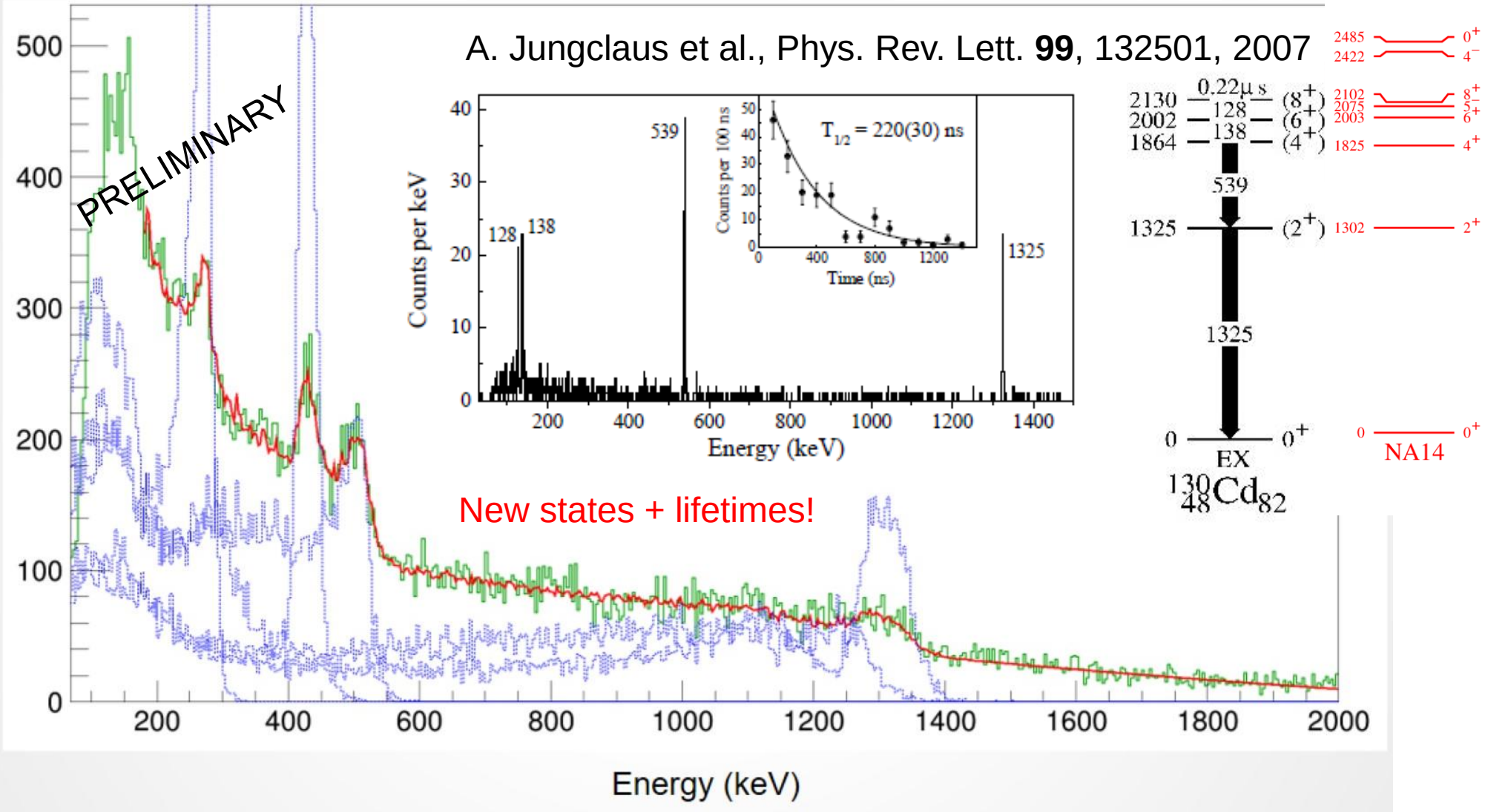




spokespersons: P. Doornenbal and K. Wimmer

Courtesy: K. Wimmer

HISPEC TYPE experiment: HICARI campaign at RIBF
Single proton knockout to ^{130}Cd
(Originally a case for FAIR)

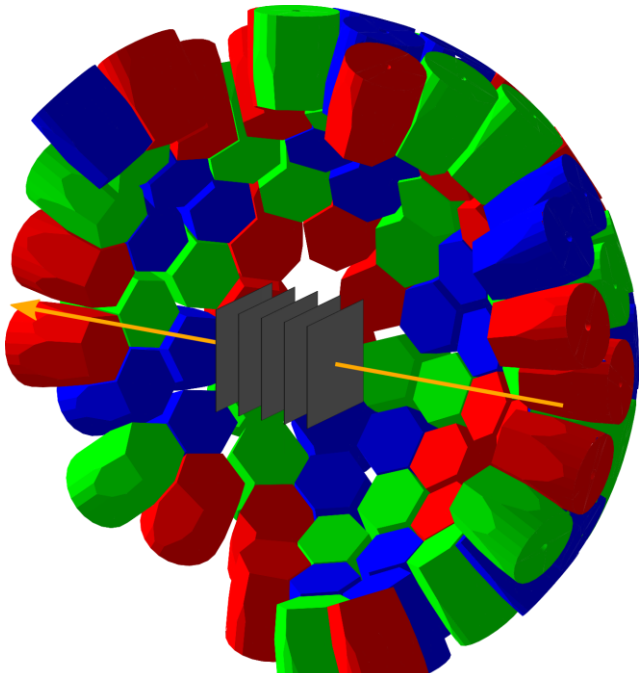


Analysis: Tom Parry (U. of Surrey), Michael Armstrong (GSI/U. Cologne), Zs. Podolyak, M.G.

LISA: LIfetime measurements with Solid Active targets

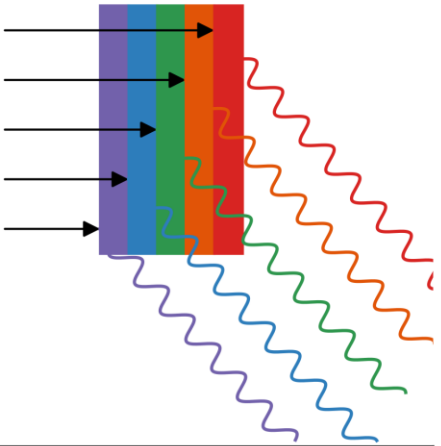
PI: K. Wimmer

Where and how collectivity emerges from the single-particle dynamics of protons and neutrons is an **open question in nuclear structure physics**

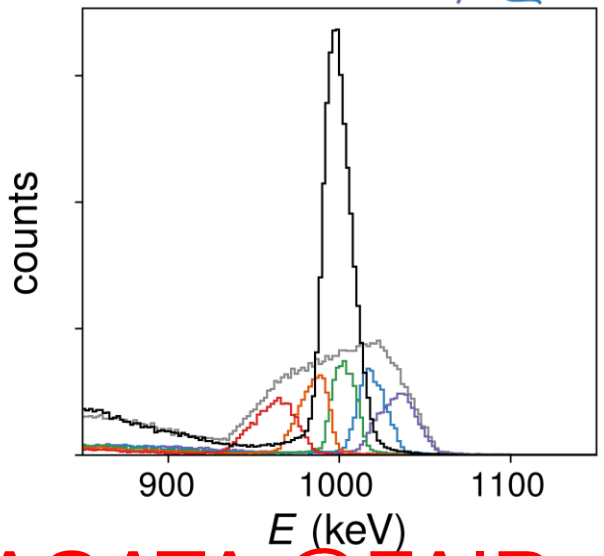


Compact array of active target detectors inside AGATA

- Energy resolution determined by unknown velocity in the target
- Several layers of active targets
- Event-by-event determination of reaction position → (β,z)



Opens new possibilities for lifetime measurements within HISPEC with AGATA at FAIR



Test run 2024
with a prototype

Physics run with HISPEC: AGATA @FAIR
after the review >2028

Additional local team activities

Accompanying Detector developments:

- Ge Planar detector response
- Timing of Ge detectors
- LISA detector array
- Fiber implanter
- Finger scintillator for high rate tracking
- Beta particle scintillators
- Development of AI/ML-based methods

Ongoing (physics) experiments at other facilities:

- IDATEN RIBF (leading role: contributing with FATIMA, several spokespersons), AGATA LNL, MINIBALL Rex-Isolde, ILL Grenoble

Third party funding (detector development and personnel):

- LISA (ERC) active diamond target
- ARTEMIS (EU) Earth quake pre-warning system
- EUROLABS
  - REMOTE OPERATIONS including ML
  - coordinating INTRANS: traveling detectors campaigns in Europe

…

Requirements for smooth realization of KSP scientific program

- In view of intense personnel rotation in 2023 (with no experiments), the maintained continuation of the local expertise is of utmost importance to be able to run main experiments next year.

- Engineering beam time (2023 and later)
  - for personnel training,
  - prototype detector test (very flexible which beam, but fragment of at least medium heavy beam) to optimize detector response for the main and test experiments

- Experimental infrastructure
  - Lab space and technical support is crucial when maintenance of detectors is required regularly (2023+)

  - in view of planned leading role in the community for improved principle of operation of Ge-detectors including DEGAS and AGATA technical support (highly specialized on Ge detectors) and lab space is required (GSI Ge-lab)

  - in view of more and more complex DAQ and computer operation and AI etc. highly specialized computer scientist (2025)

  - we try to improve remote tools/ but also increase again the on-site participation in experiments, which significantly improves their quality, therefore temporary office space (next to the experimental area) would be very important-especially at the final focal point of FRS (2023)

  - from 2026 more personnel is needed, which can be only partly supported by the collaboration and TPM (– not further specified yet)

Summary

- KSP investigates the structure of exotic nuclei and hosts HISPEC/DESPEC international collaboration
- Several DESPEC Phase-0 experiments produced the first results, many in preparation
- Flexible concept of operation at GSI/FAIR to optimize the physics outcome from available infrastructure with DESPEC setups
  - flexible in its simplest configuration
  - more space demanding in the full configuration including neutron detectors etc
- HISPEC: Before we are ready to host AGATA, only tests of ancillary equipment and intense strategy discussions on:
  - AGATA accommodation plans
  - Magnetic analyzer of the secondary-reaction products