



HISPEC/DESPEC

First nuclear structure results from FAIR Phase0

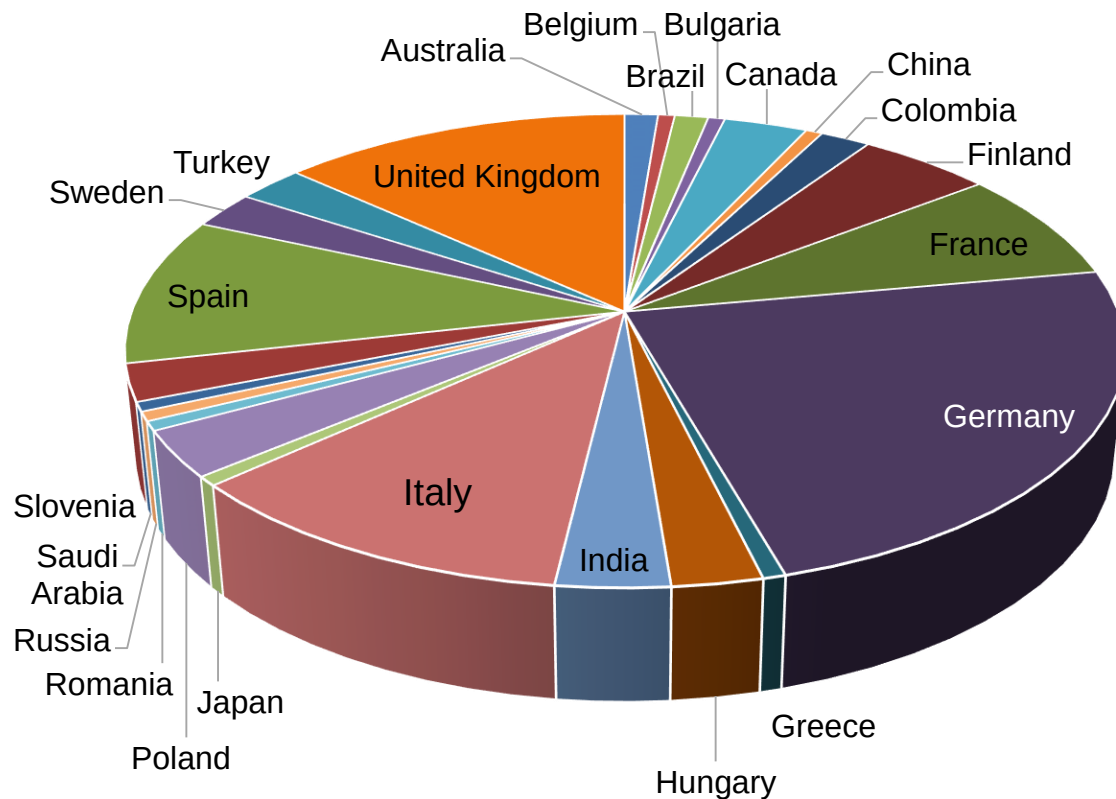
Magda Górska
for the HISPEC/DESPEC collaboration

NUSTAR - The Project

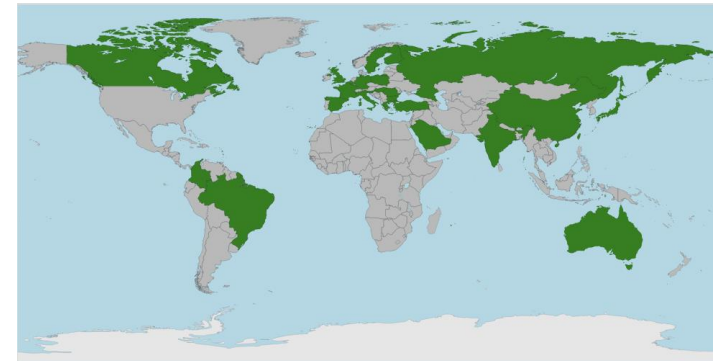
PSP code	Super-FRS	RIB production, separation, and identification
1.2.2	HISPEC/DESPEC	In-beam γ -spectroscopy at low and intermediate energy, n-decay , high-resolution γ -, β -, α -, p-, spectroscopy
1.2.3	MATS	In-trap mass measurements and decay studies
1.2.4	LaSpec	Laser spectroscopy
1.2.5	R³B	Kinematical complete reactions with relativistic radioactive beams
1.2.6	ILIMA	Large-scale scans of mass and lifetimes of nuclei in ground and isomeric states
1.2.10	Super-FRS	High-resolution spectrometer experiments
1.2.11	SHE	Synthesis and study of super-heavy elements
1.2.8	ELISE(*)	Elastic, inelastic, and quasi-free e ⁻ -A scattering
1.2.9	EXL(*)	Light-ion scattering reactions in inverse kinematics



HISPEC-DESPEC Collaboration



~230 members , 24 countries
(PhD holders+ Students)



Management:

G.Benzoni (INFN Mi) Spokesperson
P.Reiter (Uni. Cologne) Deputy
M.Górska (GSI) Local Project Manager
J.Gerl (GSI) Liason ad BR

HISPEC-DESPEC Scientific Goals

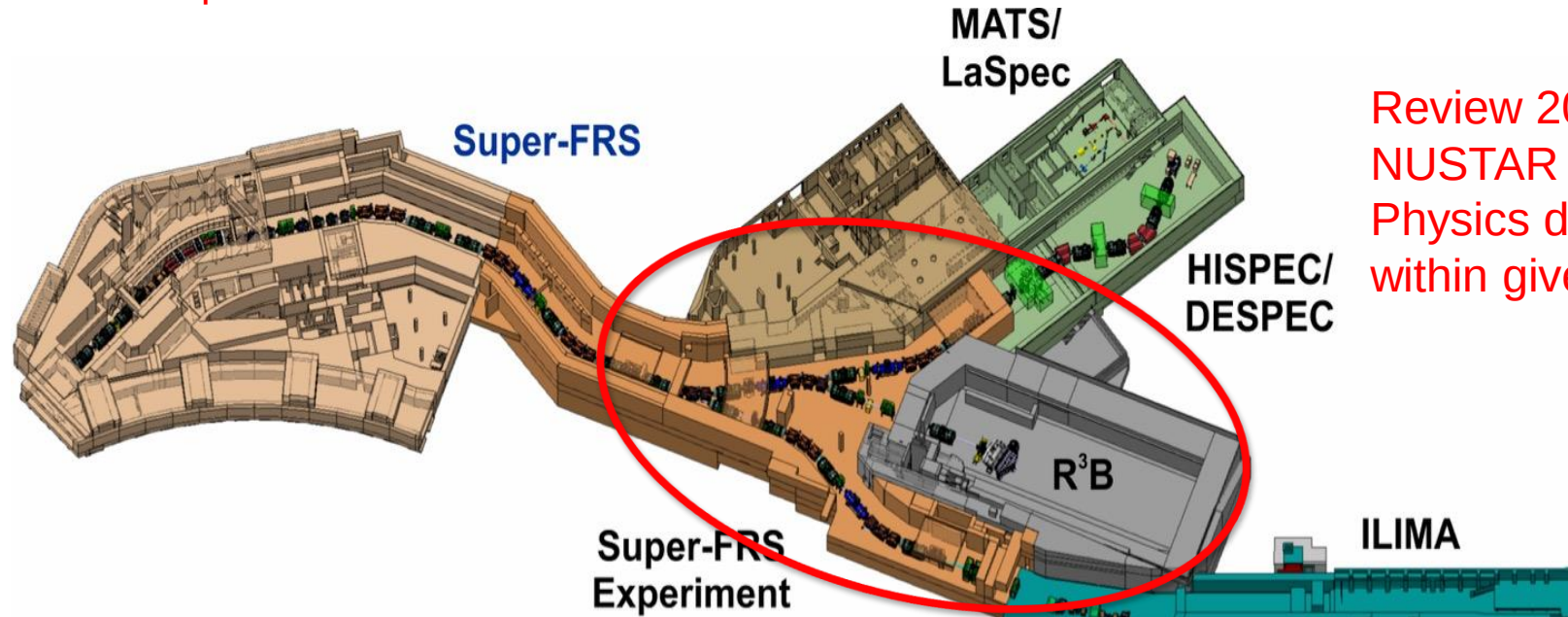
→ Spectroscopic studies both in-beam (HISPEC) and with stopped ions (DESPEC)

Key goals using unique GSI-FAIR beams:

- Approach the r-process path along $N=126$: **nucleosynthesis of heavy nuclei**
- Evolution of the shell structure and exotic nuclear shapes **in uncharted nuclear territory**

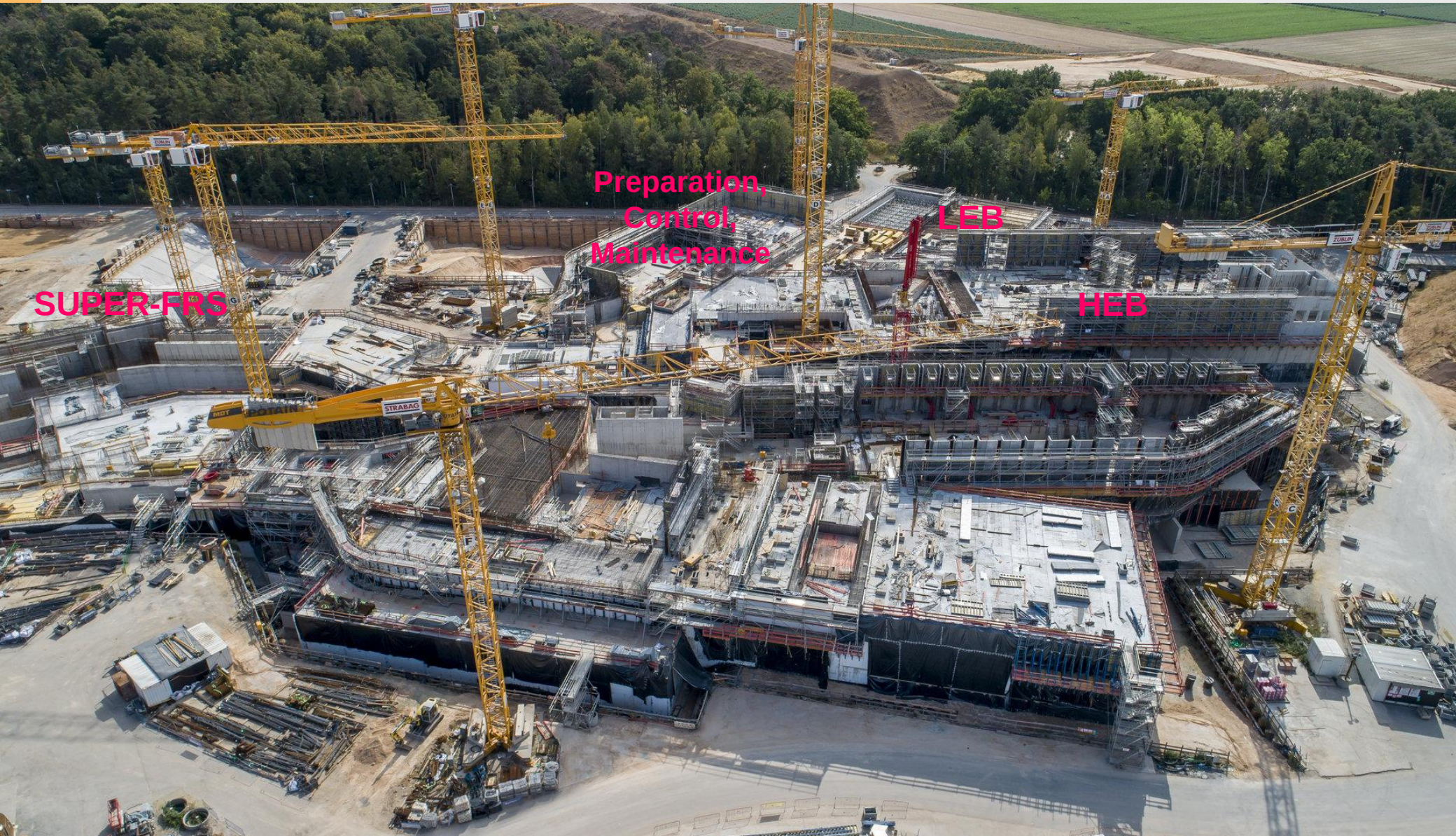
The strength of HISPEC/DESPEC:

Use combination of unique detectors for complete spectroscopy on secondary beams with yields as low as **one ion per hour**



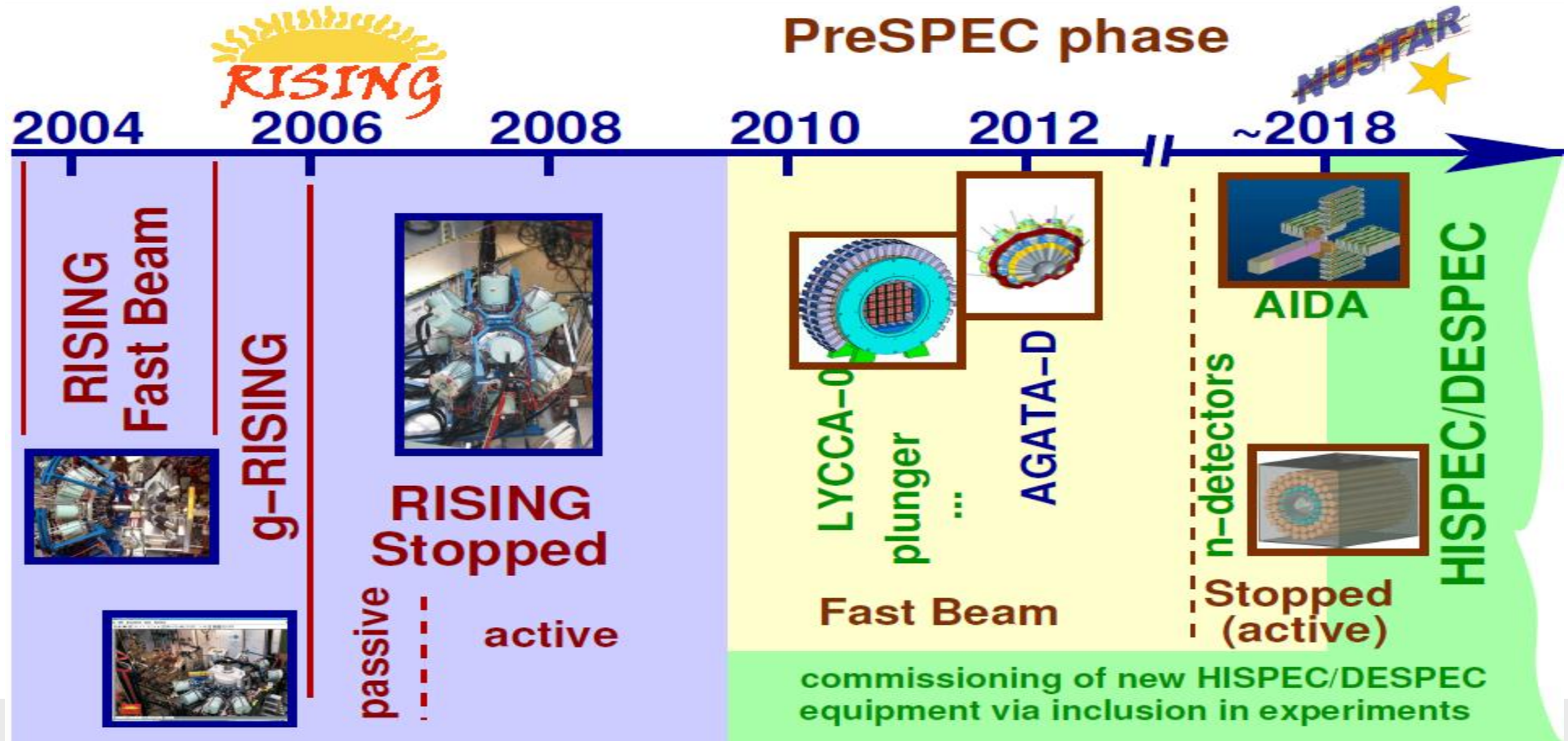
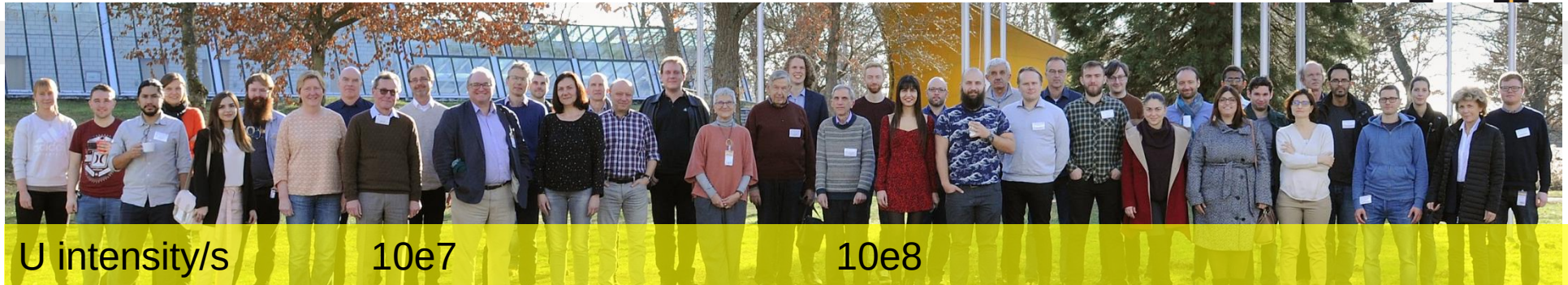
Review 2022 outcome:
NUSTAR very attractive!
Physics driven approach
within given constraints!

FAIR: August 2022 construction status

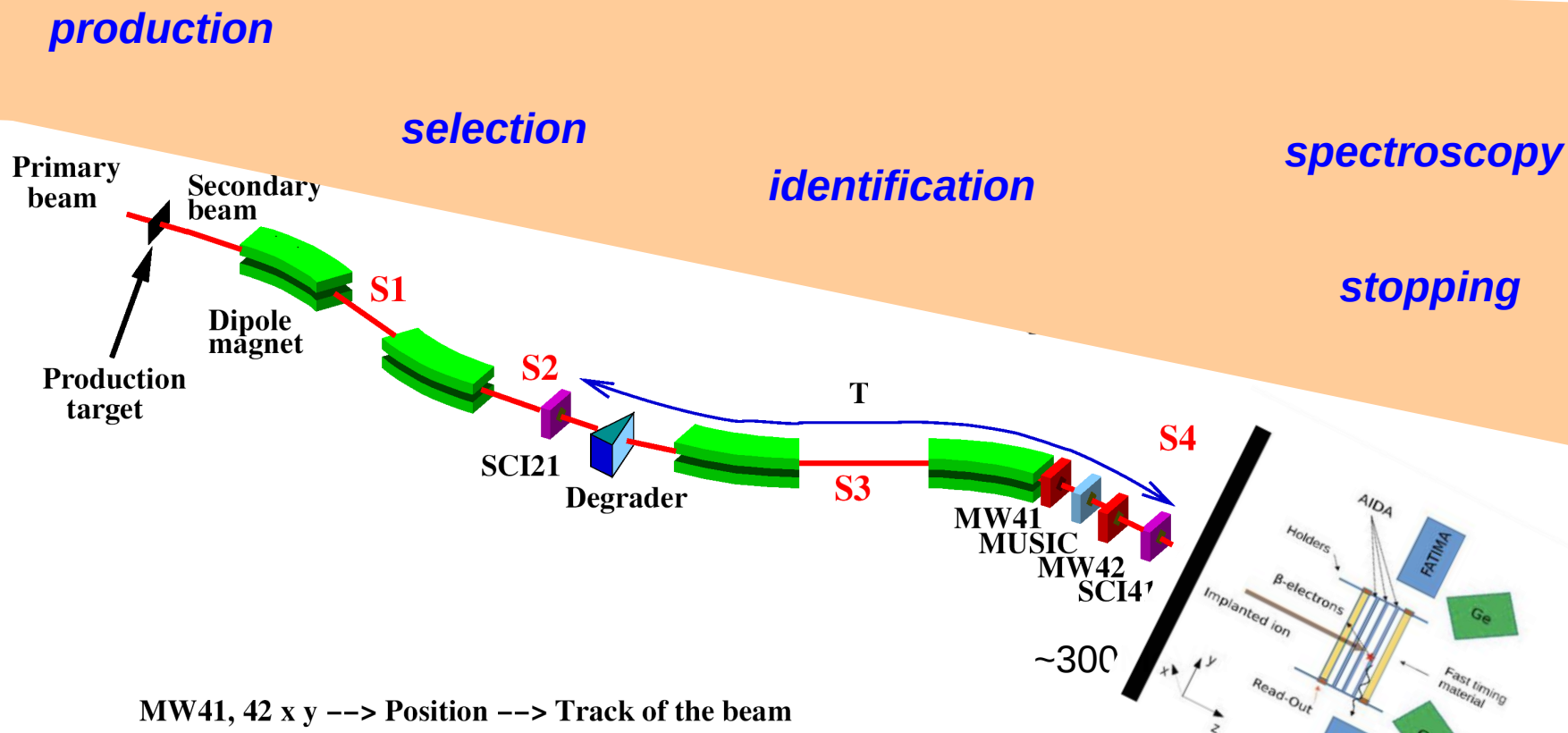


HISPEC/DESPEC collaboration

FAIR
230 scientists from 24 countries



DESPEC: Experiments with Stopped Beams 2020



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

MUSIC ---> dE

SCI 21, 41 ---> TOF ---> β

D. Magnet ---> B ρ

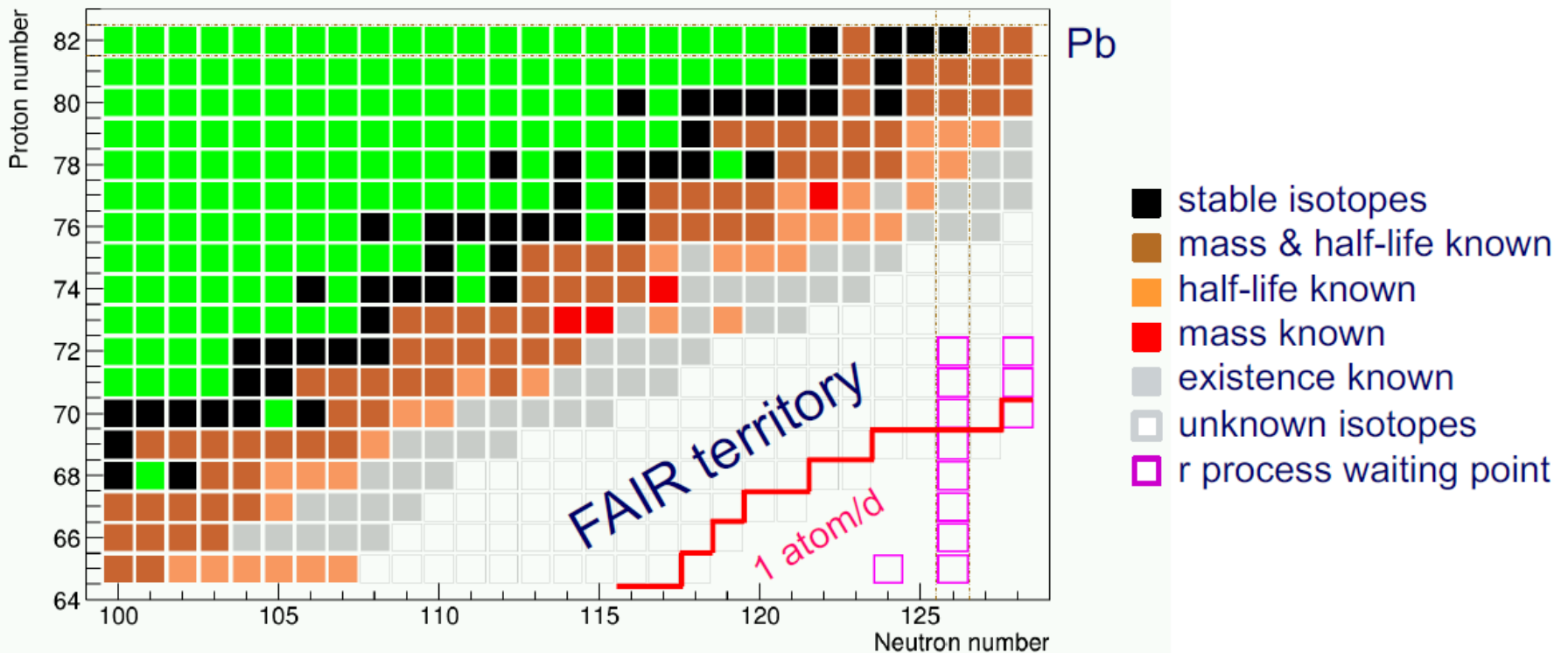
} ---> Z

} ---> A/Q

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

Towards the r process waiting points at the N=126 shell closure

Understanding the **3rd r-process abundance peak** by studying neutron-rich isotopes towards the **N=126 shell closure** and their ground-state and decay properties

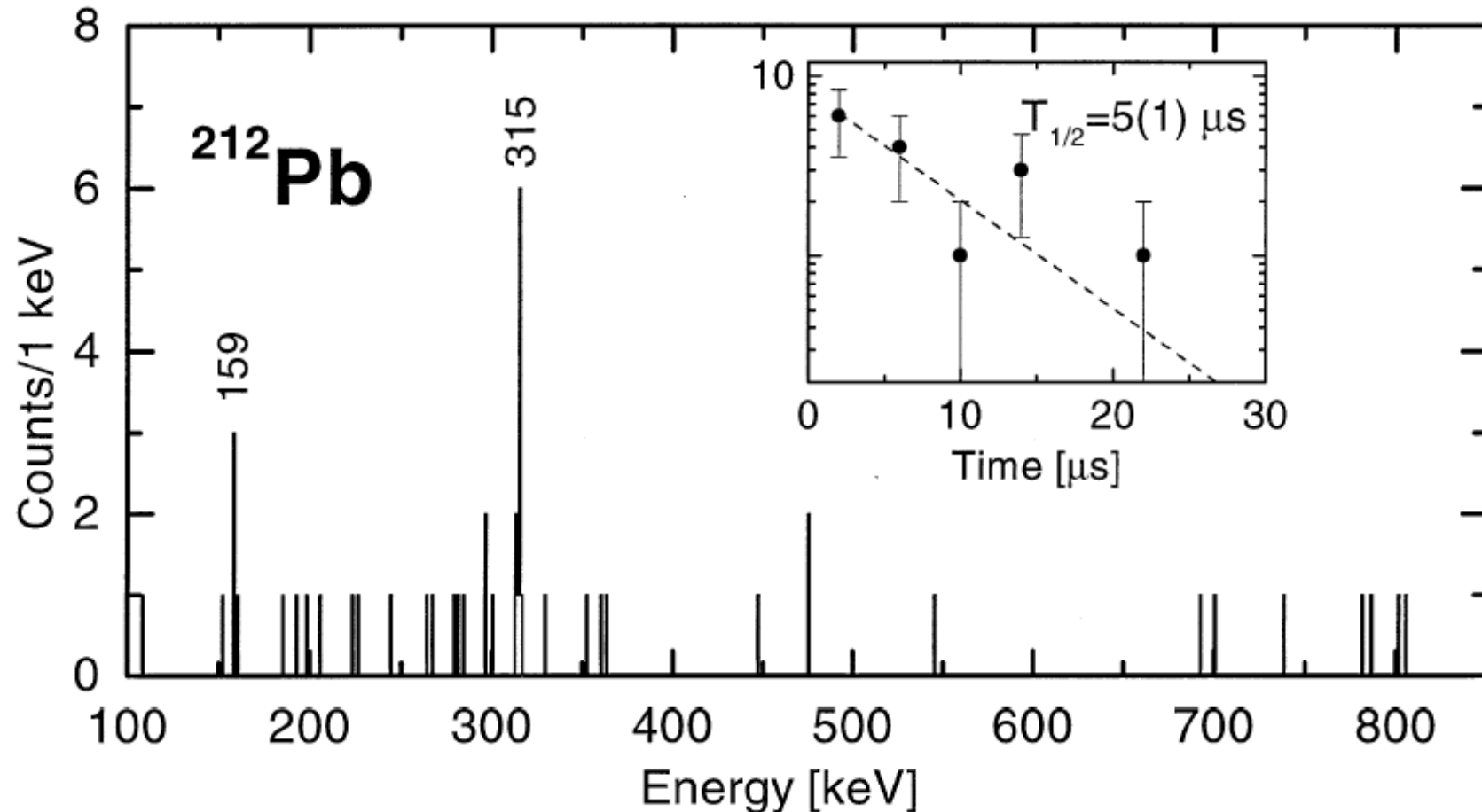


Each improvement (FRS → Super-FRS; SIS18 → SIS100)
will bring us deeper into the unknown territory

courtesy: W. Korten

DESPEC: very sensitive!

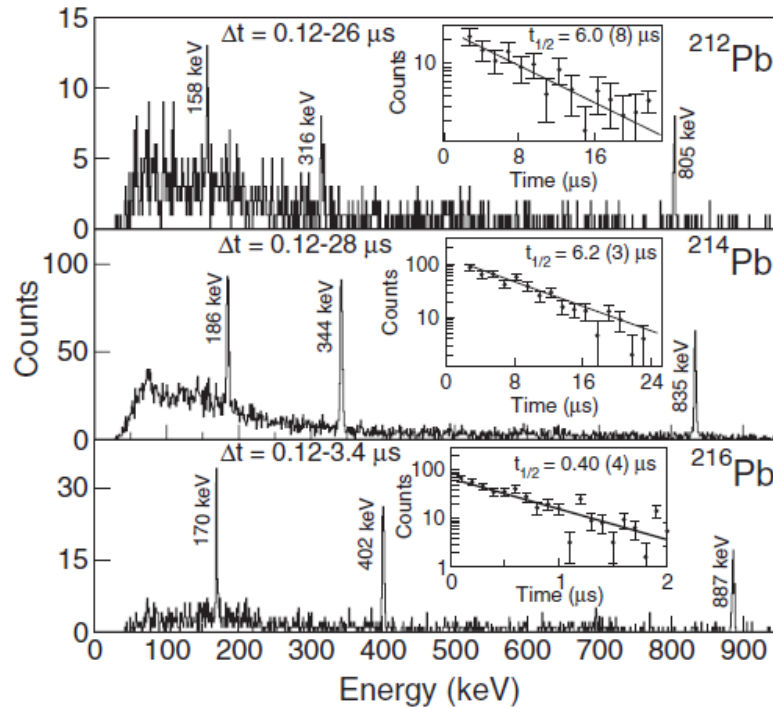
370 implanted ^{212}Pb ions!



decay of the $\text{vg}_{9/2}^2 8^+$ isomer

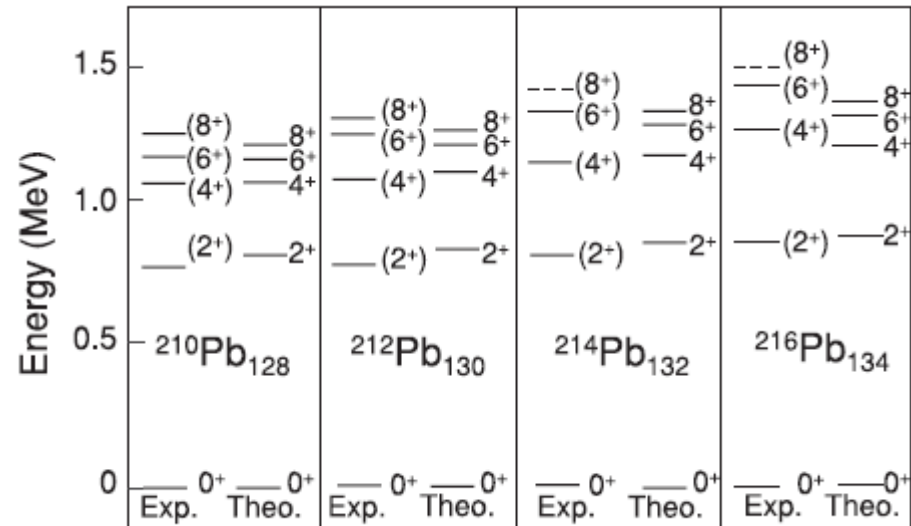
M. Pfützner et al., Phys. Lett. B 444 (1998) 32.

DESPEC sensitivity - isomer



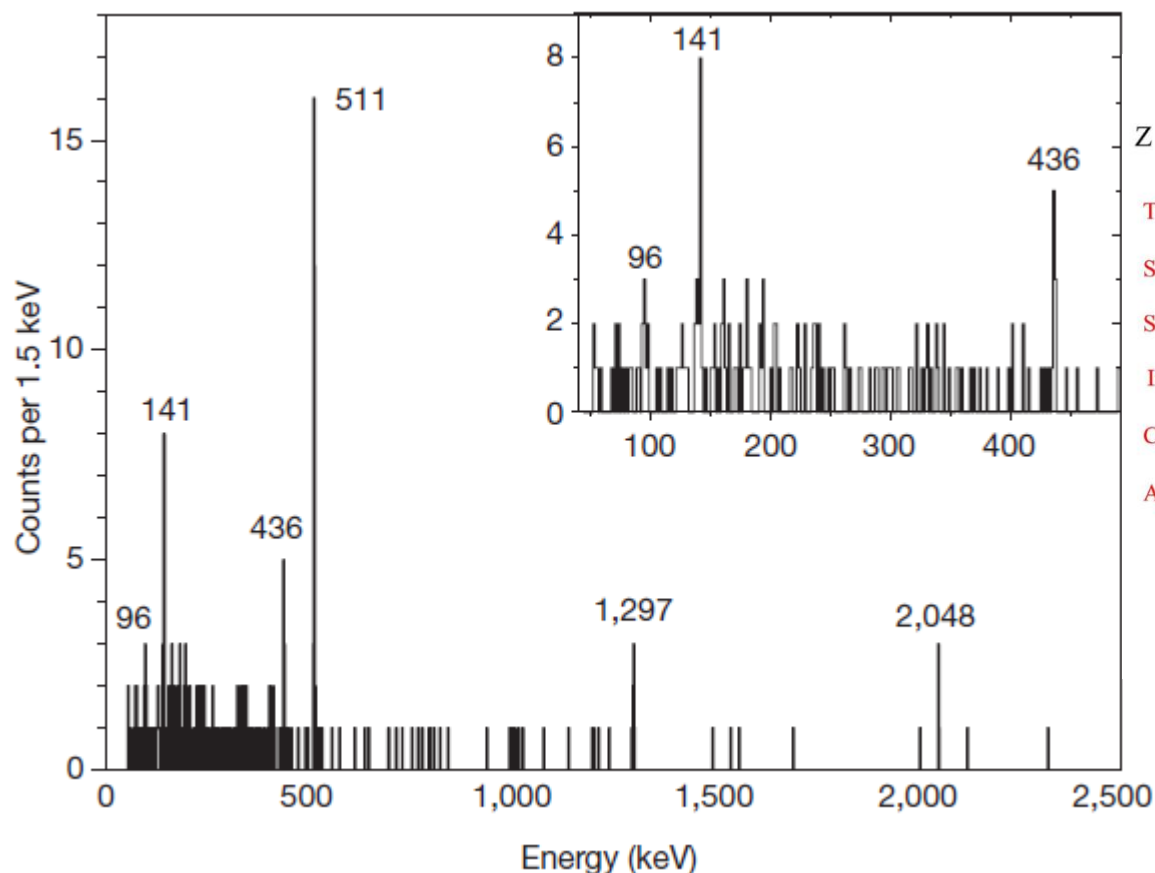
A. Gottardo et al., PRL 109, 162502 (2012)

RISING setup
15% Ge det. array efficiency



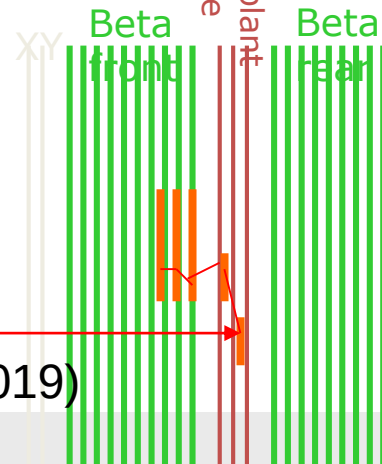
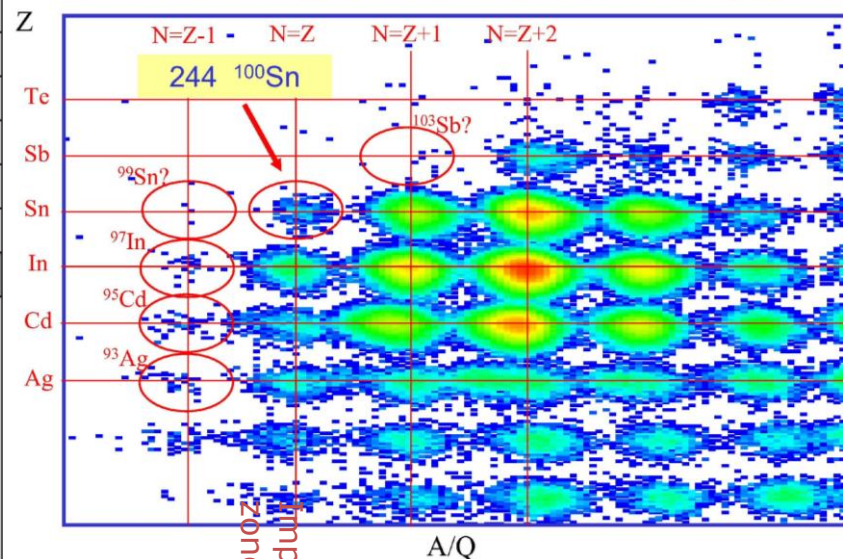
DESPEC sensitivity: β -decay of ^{100}Sn

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



<1ion/hour!

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



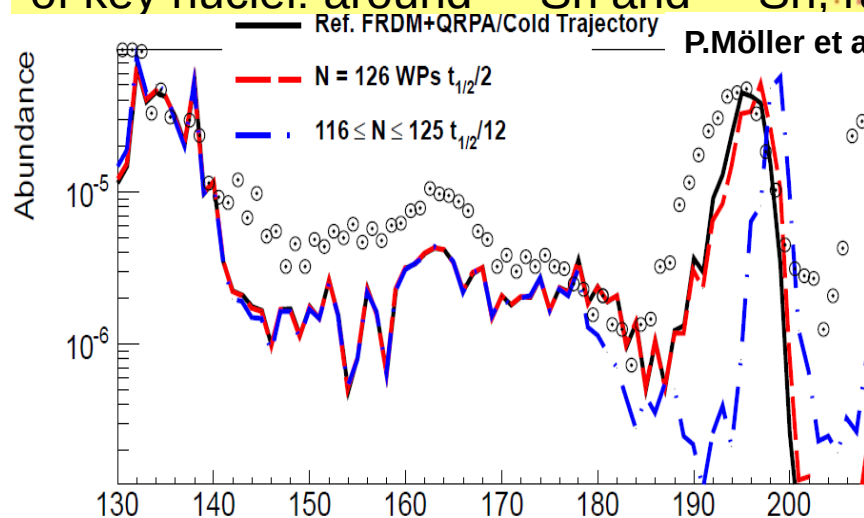
Later measurement at RIKEN with 10x statistics:

All gamma rays confirmed and no new found!

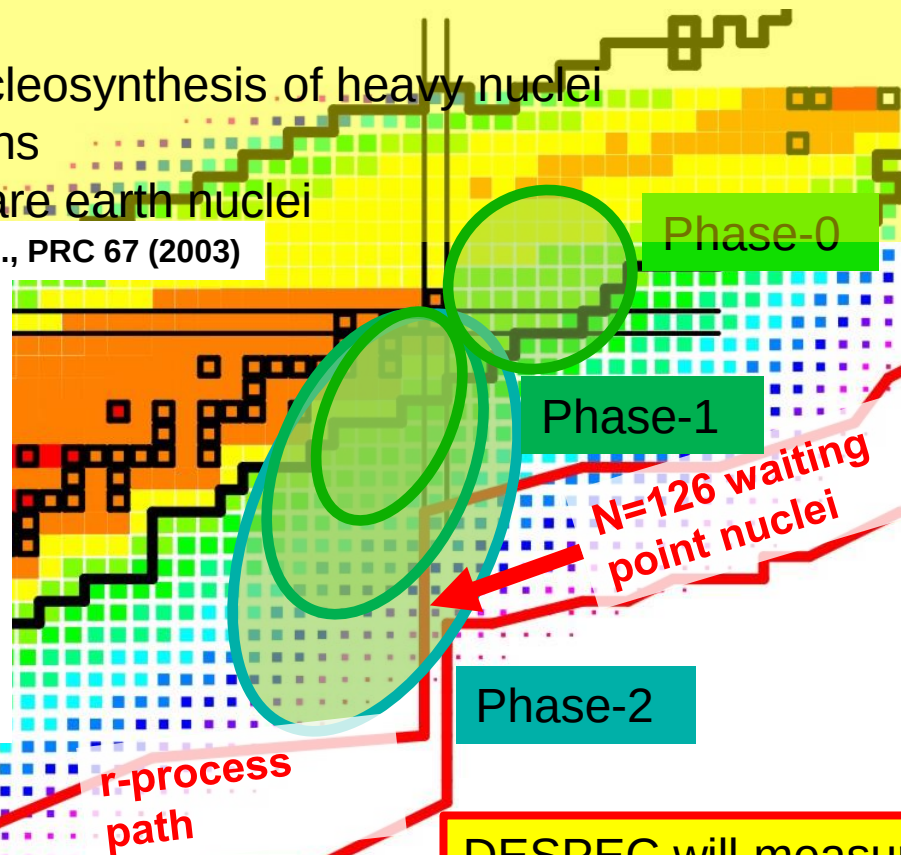
D. Lubos et al. Phys. Rev. Lett. 122, 222502 (June 2019)

DESPEC

- Comprehensive decay information from identified key nuclei at secondary beam yields $>1/h$
 - Shell structure evolution and exotic nuclear shapes near the limits of nuclear existence
 - Spectroscopic information for the nucleosynthesis of heavy nuclei
- BUT is also a competitor in lighter regions
of key nuclei: around ^{100}Sn and ^{132}Sn , rare earth nuclei



P.Möller et al., PRC 67 (2003)



Mass abundances depend on the detailed structure of $N \sim 126$ nuclei around

C Domingo-Pardo et al 2016 *J. Phys.: Conf. Ser.* **665** 012045

Mendoza-Temis, Wu, K. Langanke, G. Martinez-Pinedo, Bauswein, Janka

Q. Zhi, E. Caurier, J. J. Cuenca-Garcia, K. Langanke, G. Martinez-Pinedo, J.

N. Nishimura, Zs. Podolyák, D-L. Fang, T. Suzuki, PLB 756, 273 (2016)

DESPEC will measure:

- β -lifetimes
- neutron-branching ratios
- strength distributions
- level structure

DESPEC- approaching the frontier of nuclear existence

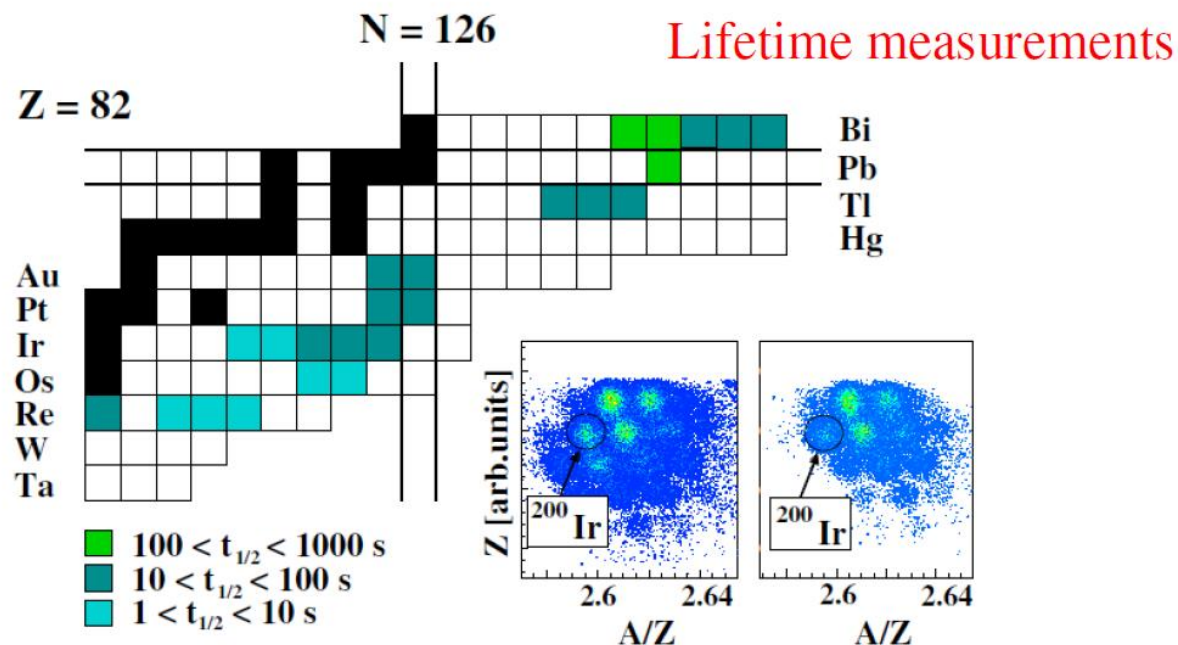
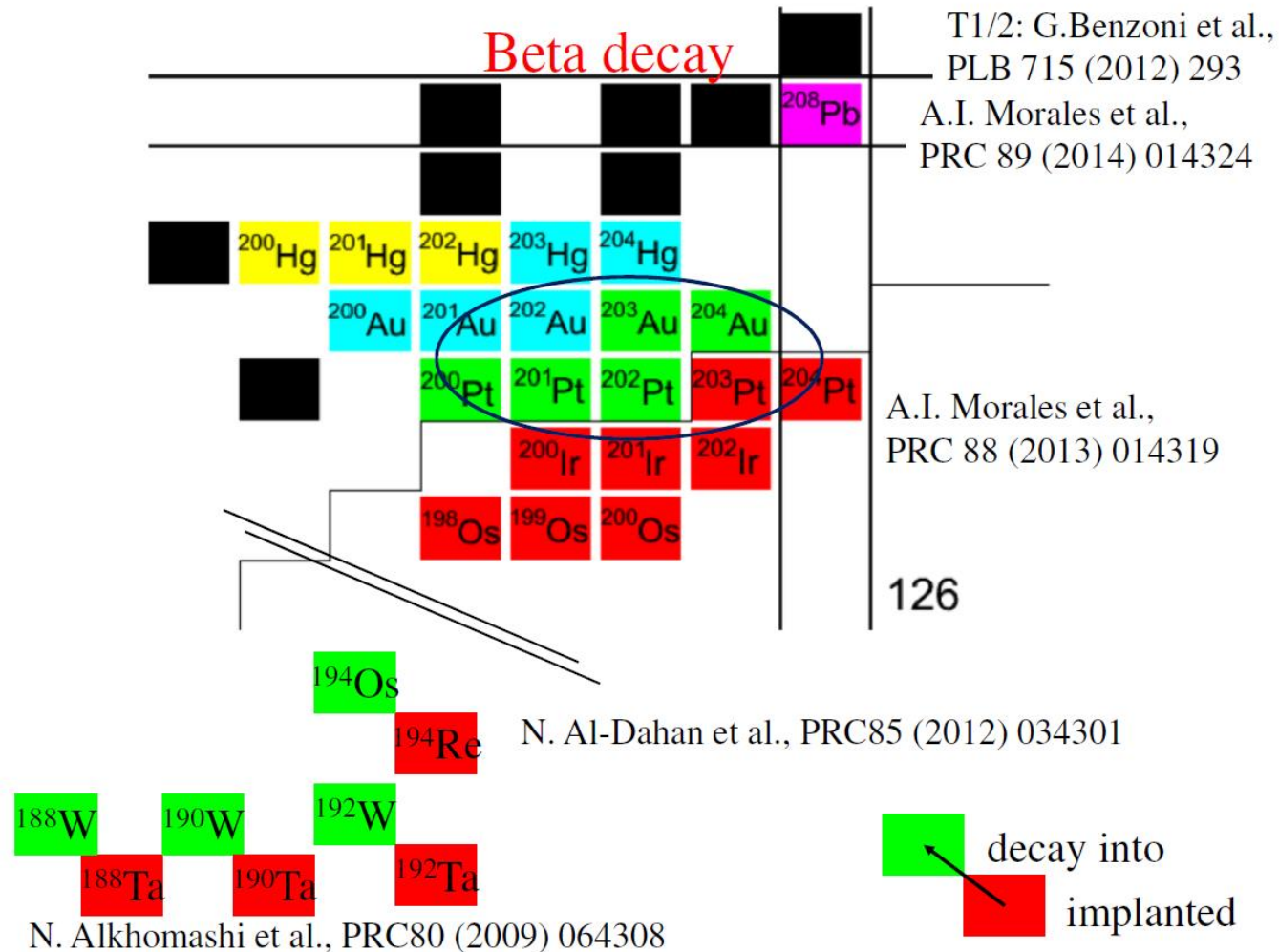


FIG. 1 (color online). Neutron-rich $N \sim 126$ region analyzed during the stopped beam RISING campaign. Measured half-lives are shown in color scale. Inset: Identification plots for Z as a function of A/Z at the final focal plane of the separator (left) and in the active stopper (right).

A.I. Morales et al., Phys. Rev. Lett. 113, 022702 (2014)

DESPEC- approaching the frontier of nuclear existence

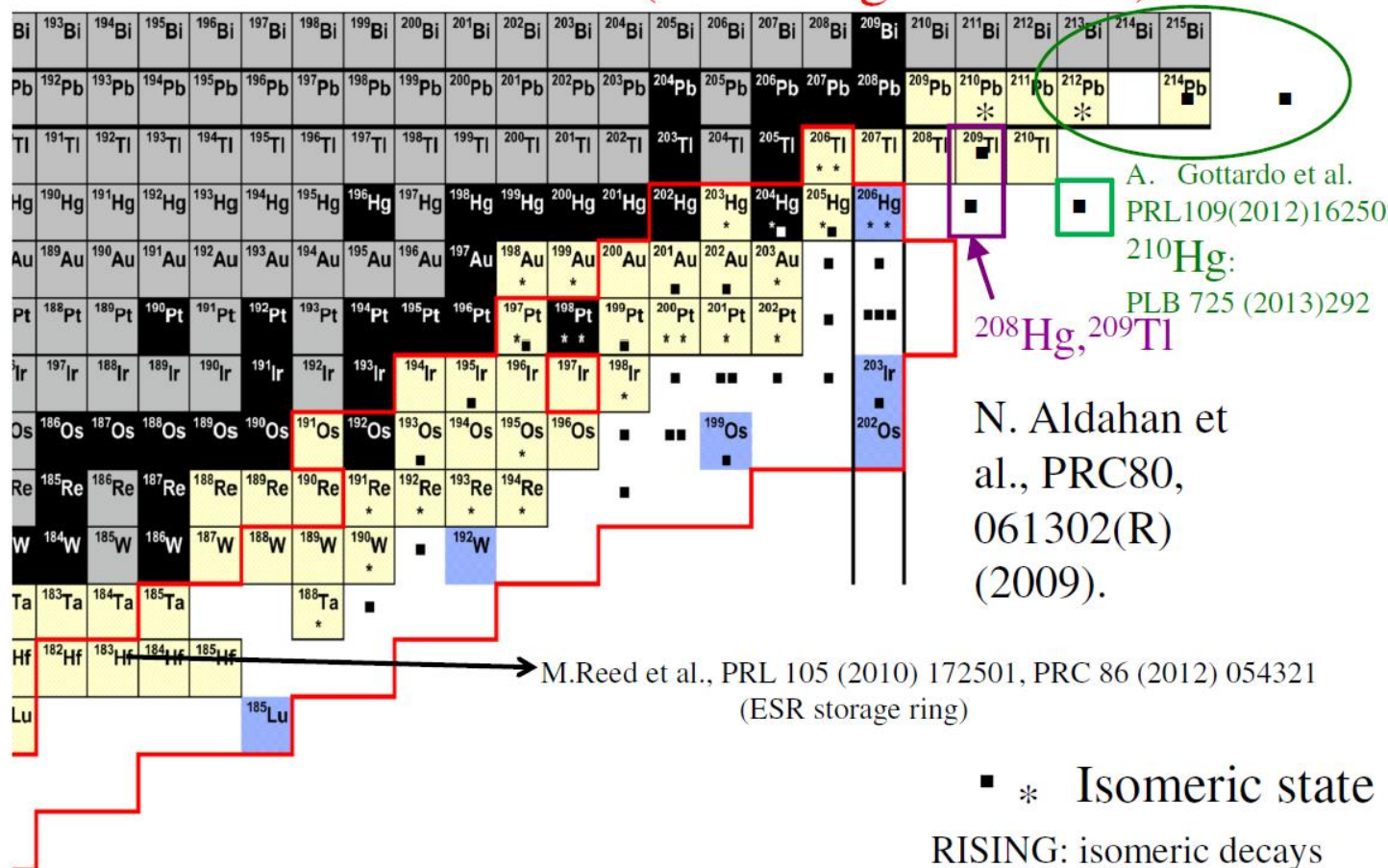


DESPEC- approaching the frontier of nuclear existence

J.J.Valiente-Dobon et al., Phys.Lett. B 816, 136183 (2021)

L. Zago et al., Phys.Lett. B 834, 137457 (2022)

Isomeric states (from fragmentation)



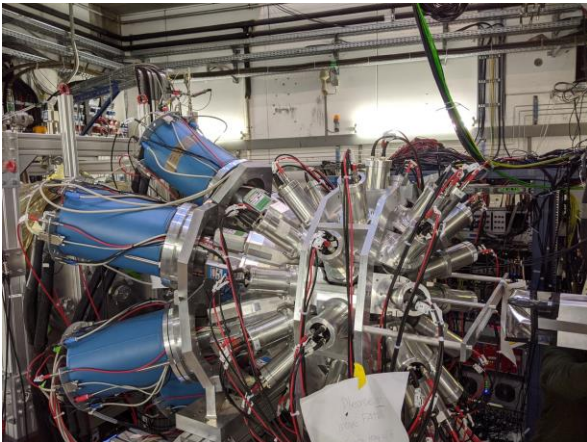
S. Steer et al., Phys. Rev. C 84 (2011) 044313

DESPEC: Decay Spectroscopy

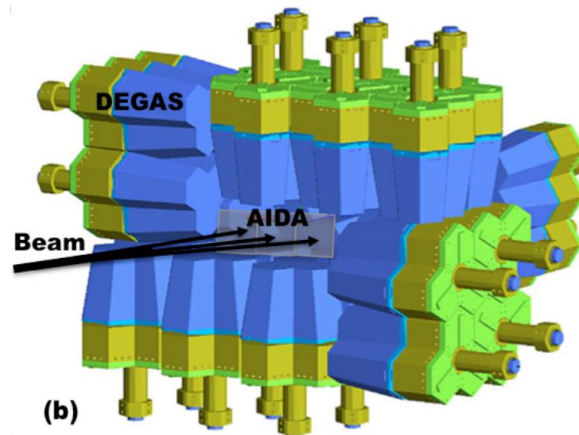
a complete picture of the isomer and β -decay process requires both **high-resolution, high-efficiency studies** and **exclusive measurements**

- **high-resolution:** aiming at a detailed reconstruction of decay scheme. Exploits combination of AIDA+HPGe detectors, coupled to FATIMA to enhance the sensitivity to specific observables (level lifetimes)
- **high-efficiency:** Total Absorption Spectrometry technique, requires instead the use of highly efficient scintillator detectors aiming at measuring the full decay strength
- **exclusive measurements:** aiming at studying specific quantities, such as delayed neutron emission probability and spectroscopy

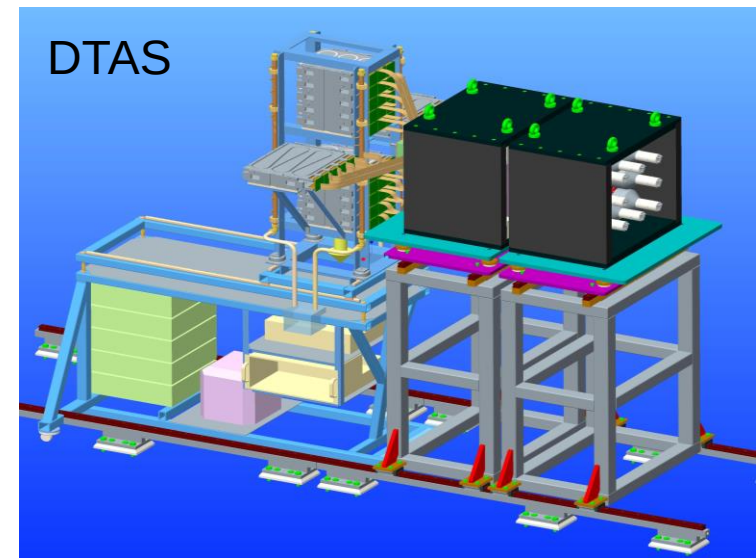
2020-2021



2022

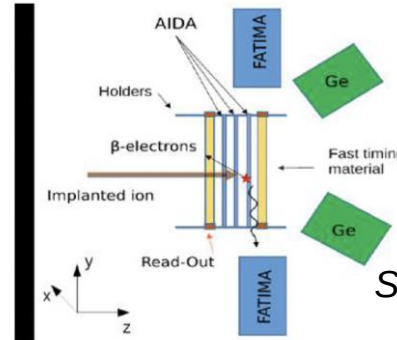


2022



SETUPS for 2020-2022

- Energy and lifetime of isomeric states and states below them
- Beta-decay
- Lifetimes → Fast-timing approach
- Level schemes



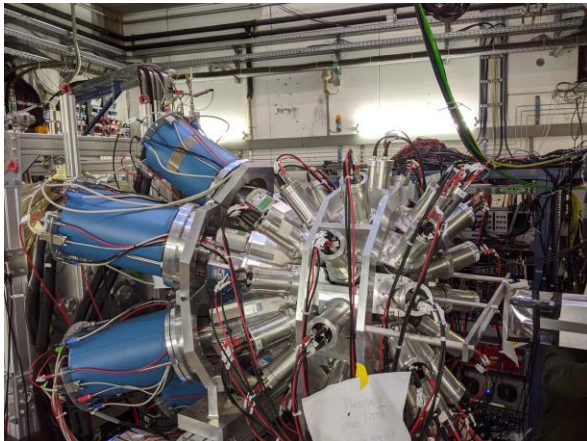
Beam in
←

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

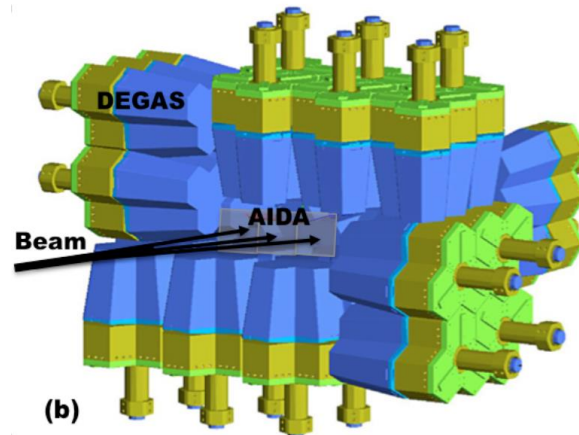
Full coverage of the implantation area with 3 DSSSD side by side

The core of the DESPEC : AIDA coupled to HPGe DEGAS detectors. The DEGAS array is slowly increasing in size, with the addition of clusters of detectors, therefore moving towards its high-efficiency compact realisation.

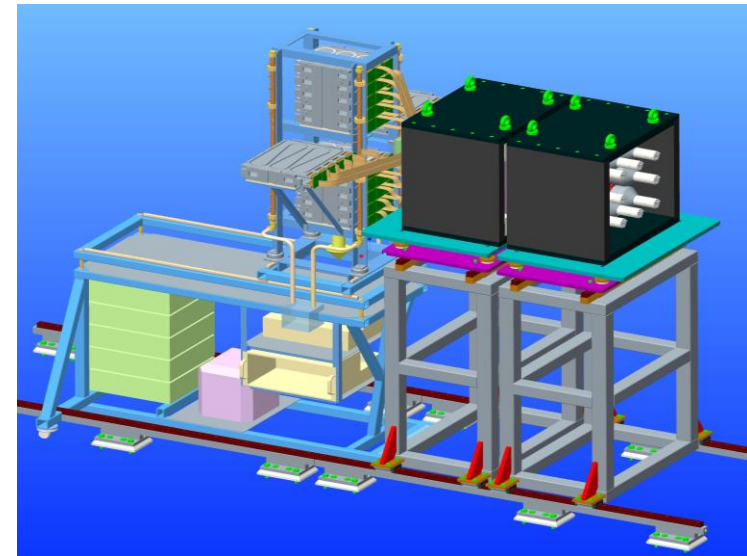
36 det. FATIMA eff. 2.9% at 1 MeV
6 GTC DEGAS or GALILEO
eff. 3% at 1 MeV



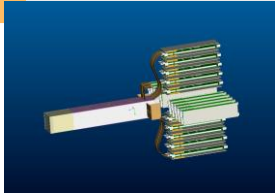
28 DEGAS eff. 18% at 1 MeV



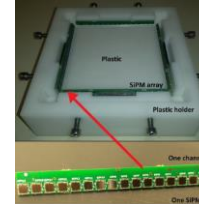
DTAS



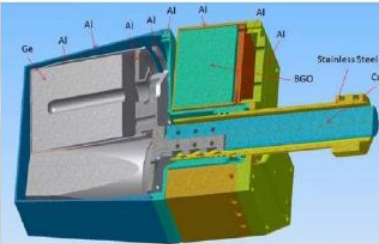
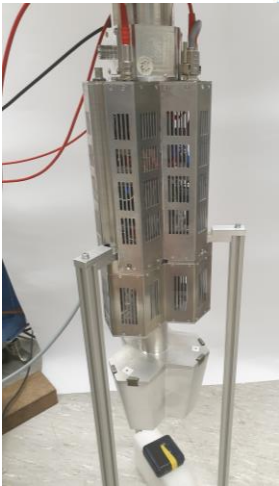
DESPEC instrumentation used in 2022



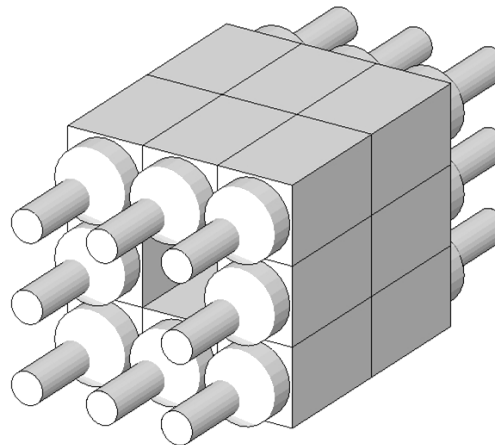
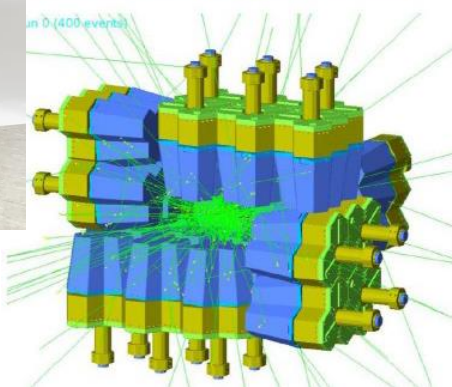
AIDA: stack of DSSSD:
 $8 \times 8 \text{ cm}^2$ and $24 \times 8 \text{ cm}^2$; 128×128 pixels
Wide dynamic range



3 mm thick plastic detector upstream
and downstream from AIDA
SiPM readout



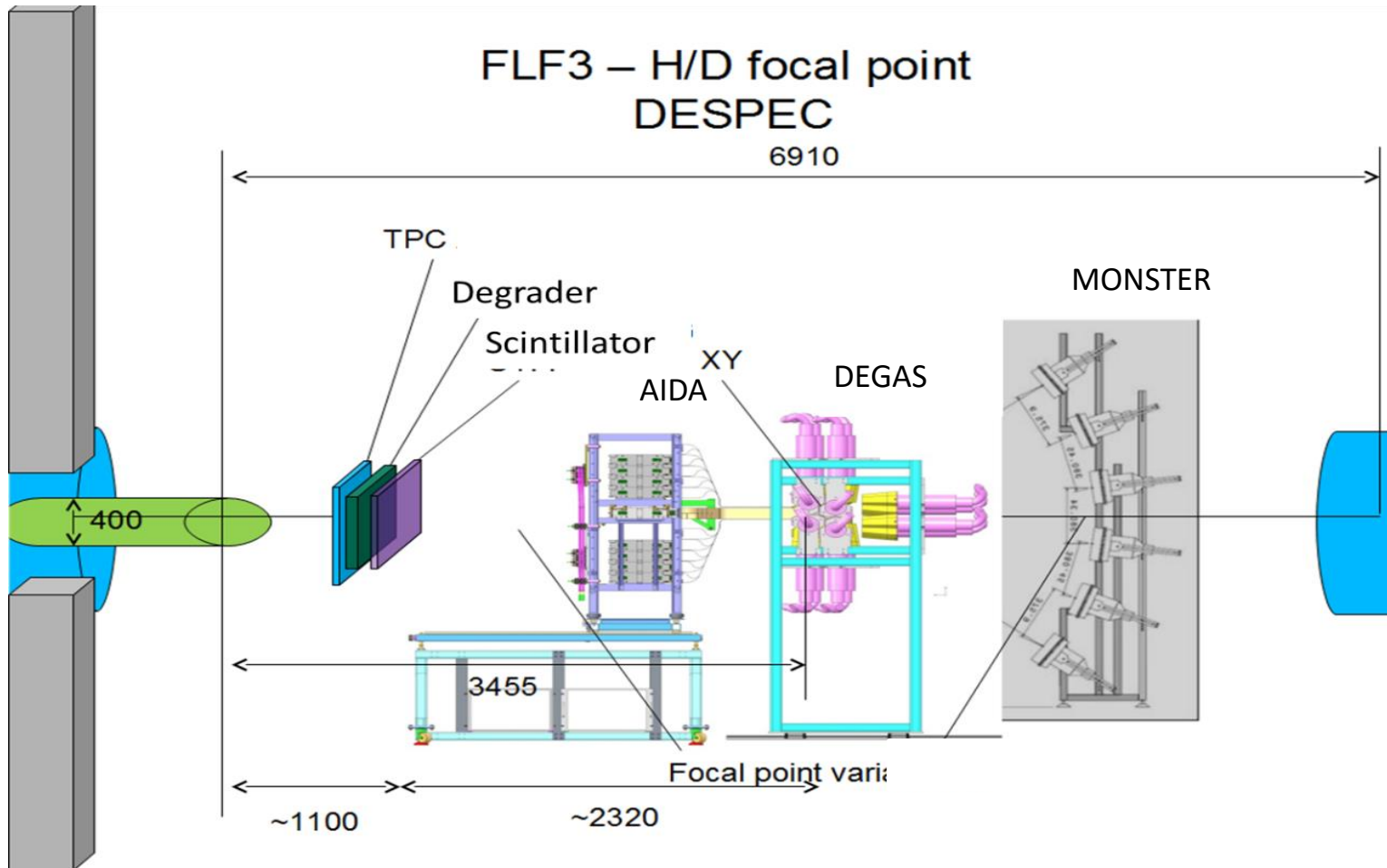
DEGAS DEcay Germanium Array Spectrometer
28 triple Clusters of Euroball Ge capsules with
BGO back-catchers and side-shields
Box configuration around $24 \times 8 \text{ cm}^2$ AIDA



DTAS gamma-calorimeter
NaI(Tl) large volume $1515 \times 25 \text{ cm}^3$
Central hole accommodating AIDA



Neutron detector





The DESPEC setup for GSI and FAIR

A.K. Mistry^{1,2,*}, H.M. Albers², T. Arıcı³, A. Banerjee², G. Benzoni⁴, B. Cederwall⁵, J. Gerl², M. Górski², O. Hall⁶, N. Hubbard^{1,2}, I. Kojouharov², J. Jolie⁷, T. Martinez⁸, Zs. Podolyák⁹, P.H. Regan^{9,10}, J.L. Tain¹¹, A. Tarifeno-Saldivia¹², H. Schaffner², V. Werner¹, G. Ağgez³, J. Agramunt¹¹, U. Ahmed¹, O. Aktas⁵, V. Alcayne⁸, A. Algora^{11,13}, S. Alhomaidhi^{1,2}, F. Amjad², C. Appleton⁶, M. Armstrong⁷, M. Balogh¹⁴, K. Banerjee¹⁵, P. Bednarczyk¹⁶, J. Benito¹⁷, C. Bhattacharya¹⁵, P. Black⁶, A. Blazhev⁷, S. Bottoni^{4,18}, P. Boutachkov², A. Bracco^{18,4}, A.M. Bruce¹⁹, M. Brunet⁹, C.G. Bruno⁶, I. Burrows²⁰, F. Calvino¹², R.L. Canavan^{9,10}, D. Cano-Ott⁸, M.M.R. Chishti⁹, P. Coleman-Smith²⁰, M.L. Cortés¹, G. Cortes¹², F. Crespi^{18,4}, B. Das⁵, T. Davinson⁶, A. De Blas¹², T. Dickel², M. Doncel²¹, A. Ertoprak^{5,3}, A. Esmaylzadeh⁷, B. Fornal¹⁶, L.M. Fraile¹⁷, F. Galtarossa¹⁴, A. Gottardo¹⁴, V. Guadilla^{11,22}, J. Ha^{23,24}, E. Haettner², G. Häfner^{25,7}, H. Heggen², P. Herrmann¹, C. Hornung², S. Jazrawi^{9,10}, P.R. John¹, A. Jokinen²⁶, C.E. Jones¹⁹, D. Kahl^{6,27}, V. Karayonchev⁷, E. Kazantseva², R. Kern¹, L. Knafla⁷, R. Knöbel², P. Koseoglou¹, G. Kosir²⁸, D. Kostyleva², N. Kurz², N. Kuzminchuk², M. Labiche²⁰, J. Lawson²⁰, I. Lazarus²⁰, S.M. Lenzi²³, S. Leoni^{4,18}, M. Llanos-Expósito¹⁷, R. Lozeva²⁵, A. Maj¹⁶, J.K. Meena¹⁵, E. Mendoza⁸, R. Menegazzo²⁴, D. Mengoni¹⁴, T.J. Mertzimekis²⁹, M. Mikolajczuk^{22,2}, B. Million⁴, N. Mont-Geli¹², A.I. Morales¹¹, P. Morral²⁰, I. Mukha², J.R. Murias¹⁷, E. Nacher¹¹, P. Napiralla¹, D.R. Napoli¹⁴, B.S. Nara-Singh³⁰, D. O'Donnell³⁰, S.E.A. Orrigo¹¹, R.D. Page³¹, R. Palit³², M. Pallas¹², J. Pellumaj¹⁴, S. Pelonis²⁹, H. Pentilla²⁶, A. Pérez de Rada⁸, R.M. Pérez-Vidal¹⁴, C.M. Petrache²⁵, N. Pietralla¹, S. Pietri², S. Pigliapoco²⁴, J. Plaza⁸, M. Poletti^{4,18}, C. Porzio^{4,18}, V.F.E. Pucknell²⁰, F. Recchia²³, P. Reiter⁷, K. Rezynekina²⁴, S. Rinta-Antila²⁶, E. Rocco², H.A. Rösch^{2,1}, P. Roy^{15,2}, B. Rubio¹¹, M. Rudigier¹, P. Ruotsalainen²⁶, S. Saha³³, E. Şahin^{1,2}, Ch. Scheidenberger², D.A. Seddon³¹, L. Sexton⁶, A. Sharma³⁴, M. Si²⁵, J. Simpson²⁰, A. Smith³⁵, R. Smith²⁰, P.A. Söderström²⁷, A. Sood⁵, A. Soylu³⁶, Y.K. Tanaka³⁷, J.J. Valiente-Dobón¹⁴, P. Vasileiou²⁹, J. Vasiljevic⁵, J. Vesic²⁸, D. Villamarin⁸, H. Weick², M. Wiebusch², J. Wiederhold¹, O. Wieland⁴, H.J. Wollersheim², P.J. Woods⁶, A. Yaneva⁷, I. Zanon¹⁴, G. Zhang^{23,24}, J. Zhao^{2,38}, R. Zidarova¹, G. Zimba²⁶, A. Zyrlidou²⁹



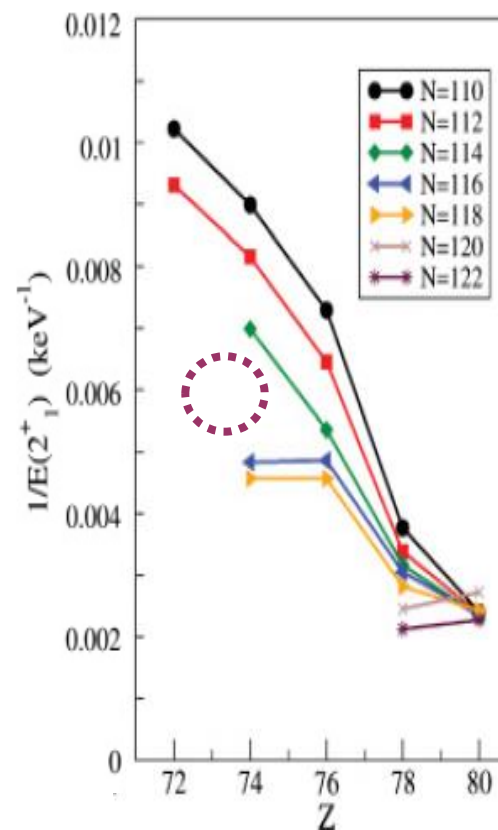
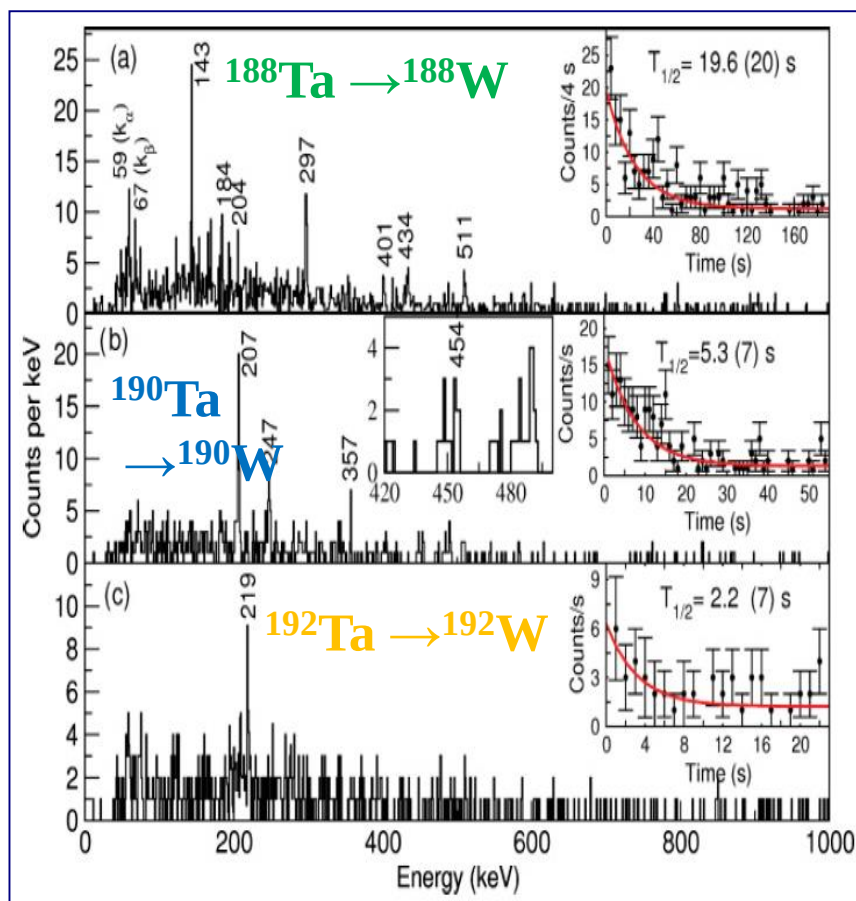
DESPEC NIM

DESPEC sensitive to:

- very exotic nuclei
- to extract nuclear structure information for each state of which lifetime can be measured (10ps-100s) 13 orders of magnitude!
- to extract nuclear structure information for each type of the decay

β^- -delayed spectroscopy of neutron-rich tantalum nuclei: Shape evolution in neutron-rich tungsten isotopes

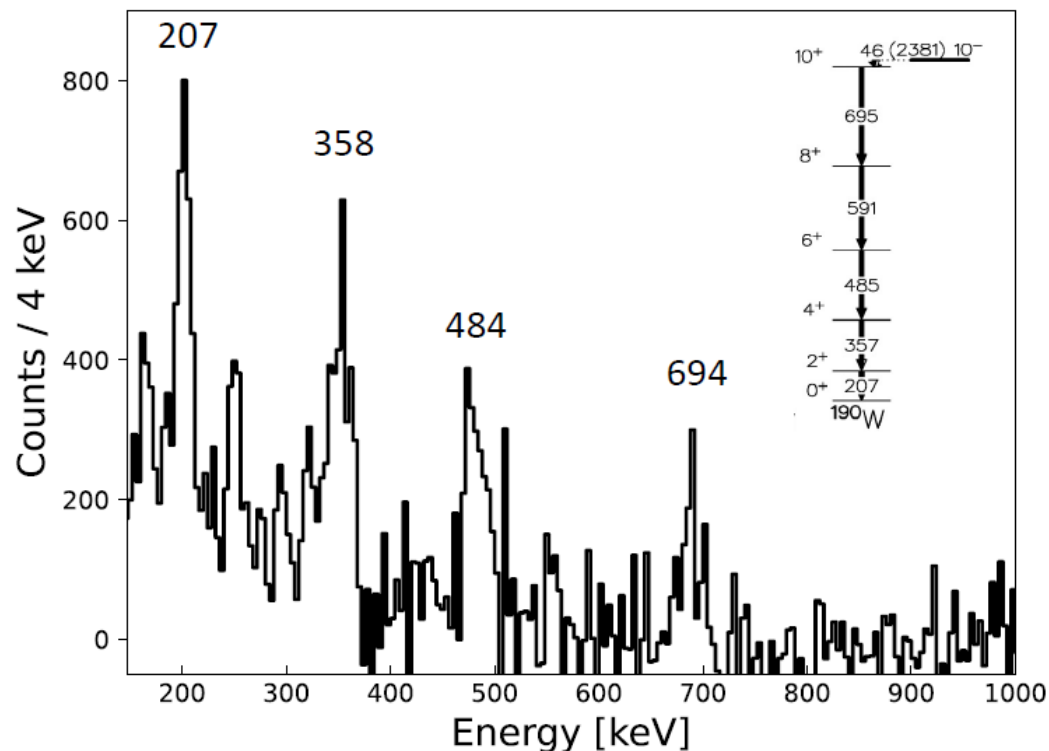
N. Alkhomashi,^{1,*} P. H. Regan,¹ Zs. Podolyák,¹ S. Pietri,¹ A. B. Garnsworthy,¹ S. J. Steer,¹ J. Benlliure,² E. Caserejos,² R. F. Casten,³ J. Gerl,⁴ H. J. Wollersheim,⁴ J. Grebosz,⁵ G. Farrelly,¹ M. Górska,⁴ I. Kojouharov,⁴ H. Schaffner,⁴ A. Algara,^{6,7} G. Benzoni,⁸ A. Blazhev,⁹ P. Boutachkov,⁴ A. M. Bruce,¹⁰ A. M. Denis Bacelar,¹⁰ I. J. Cullen,¹ L. Cáceres,⁴ P. Doornenbal,⁴ M. E. Estevez,² Y. Fujita,¹¹ W. Gelletly,¹ R. Hoischen,^{4,12} R. Kumar,¹³ N. Kurz,⁴ S. Lalkovski,¹⁰ Z. Liu,¹⁴ C. Mihai,¹⁵ F. Molina,⁶ A. I. Morales,² D. Múcher,⁹ W. Prokopowicz,⁴ B. Rubio,⁶ Y. Shi,¹⁶ A. Tamii,¹⁷ S. Tashenov,⁴ J. J. Valiente-Dobón,¹⁸ P. M. Walker,¹ P. J. Woods,¹⁴ and F. R. Xu¹⁶



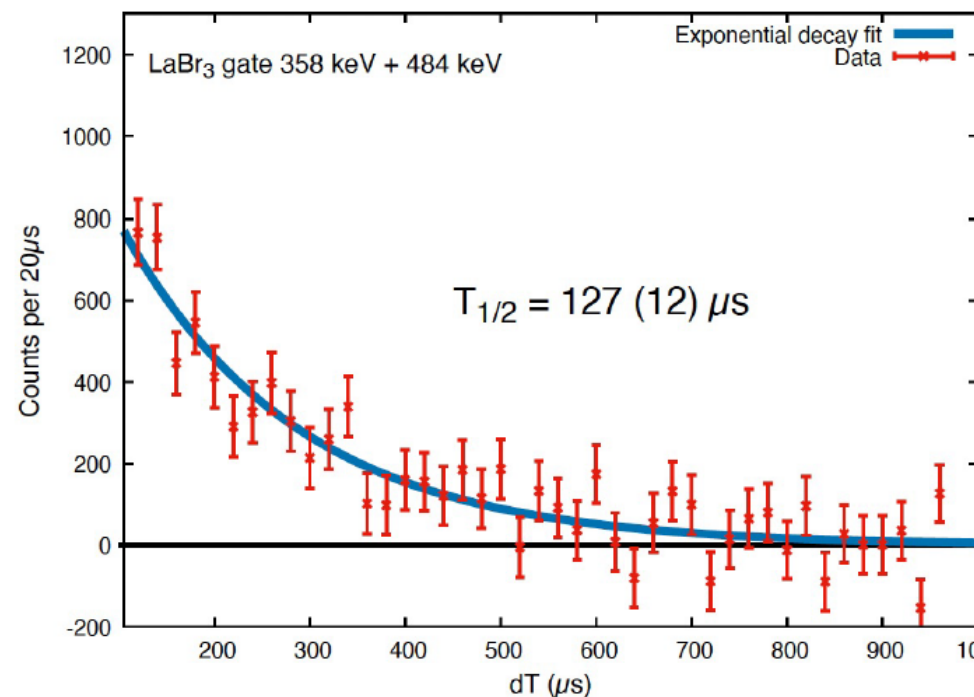
K. Nomura et al., PRC 84, 054316 (2011)

Campaign 2021

S452: Isomer Spectroscopy of ^{190}W



FATIMA ^{190}W γ -rays detected in a time period of 0-1000 μs between FRS and FATIMA (background subtraction 1000-2000 μs)



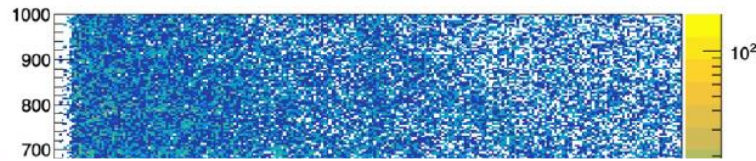
Isomer half-life of ^{190}W extracted

$T_{1/2} = 127(12) \mu\text{s}$

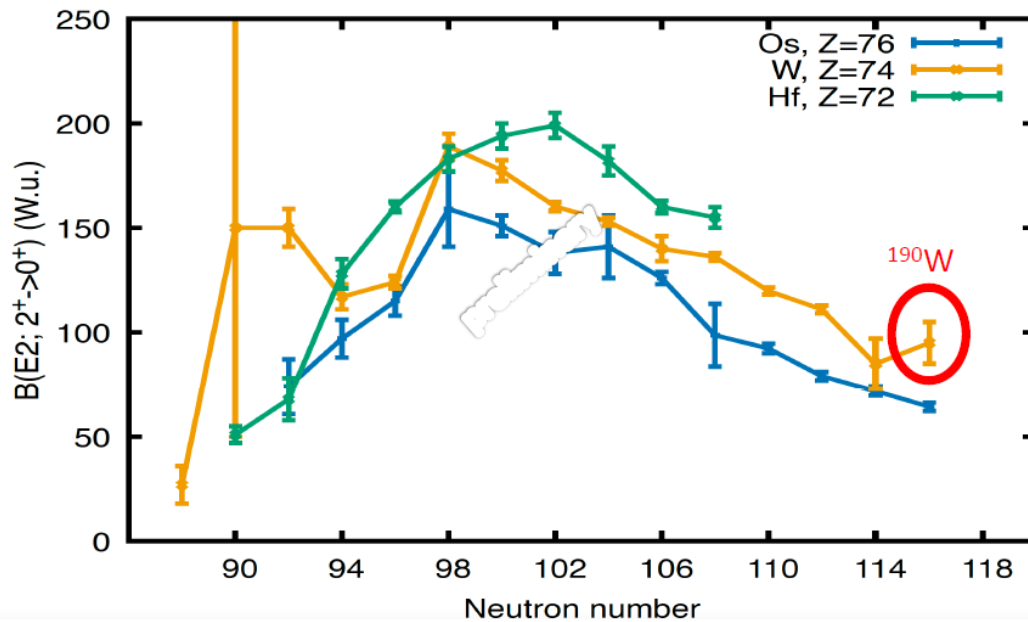
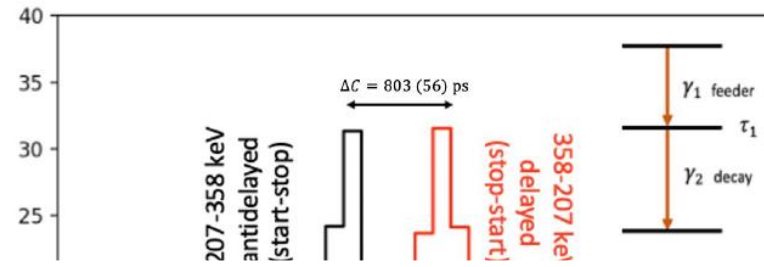
Level scheme confirmed

E. Sahin (TUD/GSI), V. Werner

Fast timing measurement :

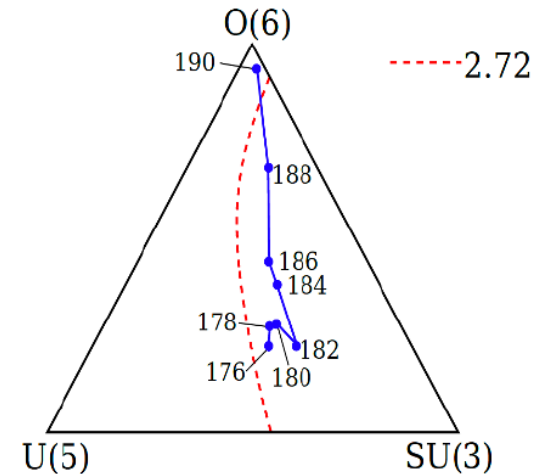


25 ps

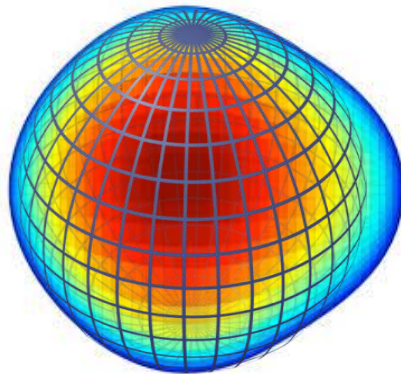


$$B(E; 2^+ \rightarrow 0^+) = 95(10) \text{ W.u.}$$

Consistent with the naively expected minimum of $B(E2)$ strength at $O(6)$ and rise beyond that point. More detailed calculations are ongoing to find whether or to what extent such a rise beyond $O(6)$.



E. Sahin (TU Darmstadt), V. Werner



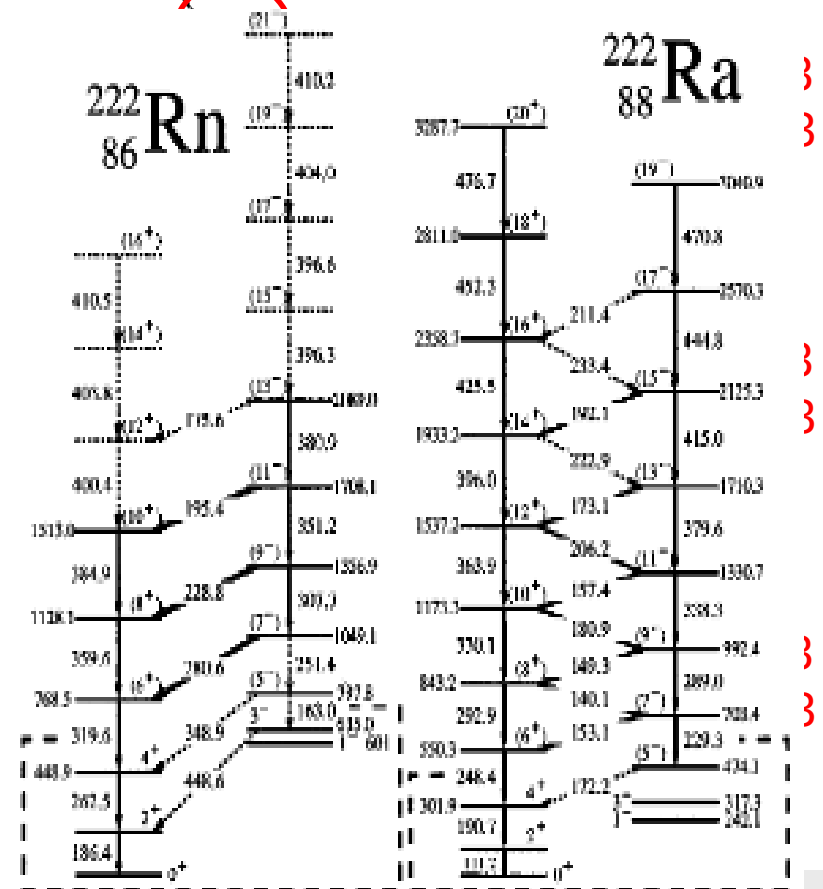
- The strongest octupole correlations are expected around v -rich $A \sim 150$ and **$A \sim 225$**
- Octupole-deformed (pear-like) shapes appear under particular conditions:

Pending questions:

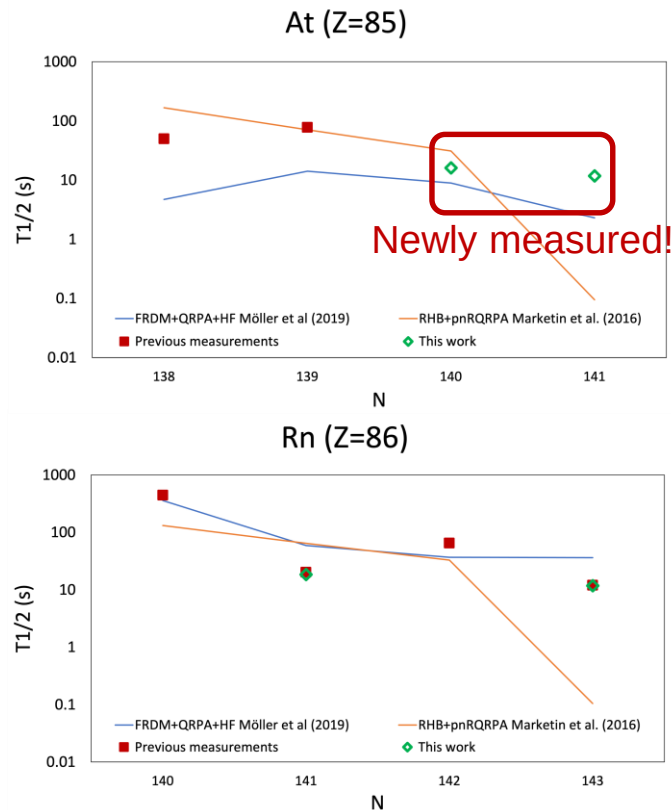
- ☐ Maximum of octupole deformation
- ☐ Static or dynamic deformation
- ☐ Role of quadrupole-octupole coupling

Particular features:

- ☐ Large $B(E1)$ transition probabilities
- ☐ Large $B(E3)$ strengths $\rightarrow$ difficult to measure
- ☐ Interleaved positive- and negative-parity states:



DESPEC 2021: The $220 < A < 230$ Po-Fr region



Goals:

- Search for octupole deformation
- Provide new β decay info to test of nuclear models for r process

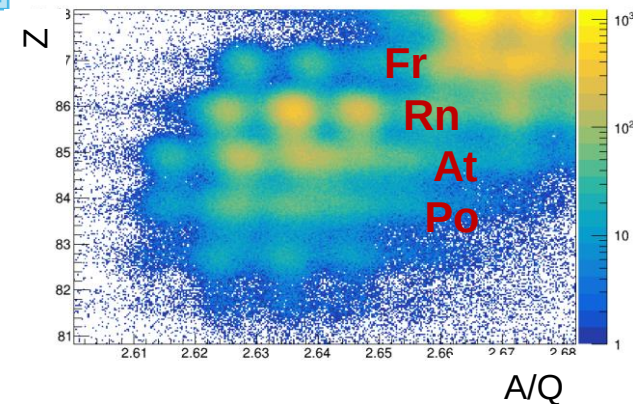
Radium Z=88	²¹⁷ Ra	²¹⁸ Ra	²¹⁹ Ra	²²⁰ Ra	²²¹ Ra	²²² Ra	²²³ Ra	²²⁴ Ra	²²⁵ Ra	²²⁶ Ra	²²⁷ Ra	²²⁸ Ra	²²⁹ Ra	²³⁰ Ra	²³¹ Ra	²³² Ra	²³³ Ra	²³⁴ Ra	²³⁵ Ra
Francium Z=87	²¹⁶ Fr	²¹⁷ Fr	²¹⁸ Fr	²¹⁹ Fr	²²⁰ Fr	²²¹ Fr	²²² Fr	²²³ Fr	²²⁴ Fr	²²⁵ Fr	²²⁶ Fr	²²⁷ Fr	²²⁸ Fr	²²⁹ Fr	²³⁰ Fr	²³¹ Fr	²³² Fr	²³³ Fr	
Radon Z=86	²¹⁵ Rn	²¹⁶ Rn	²¹⁷ Rn	²¹⁸ Rn	²¹⁹ Rn	²²⁰ Rn	²²¹ Rn	²²² Rn	²²³ Rn	²²⁴ Rn	²²⁵ Rn	²²⁶ Rn	²²⁷ Rn	²²⁸ Rn	²²⁹ Rn	²³⁰ Rn	²³¹ Rn		
Astatine Z=85	²¹⁴ At	²¹⁵ At	²¹⁶ At	²¹⁷ At	²¹⁸ At	²¹⁹ At	²²⁰ At	²²¹ At	²²² At	²²³ At	²²⁴ At	²²⁵ At	²²⁶ At	²²⁷ At	²²⁸ At	²²⁹ At			
Polonium Z=84	²¹³ Po	²¹⁴ Po	²¹⁵ Po	²¹⁶ Po	²¹⁷ Po	²¹⁸ Po	²¹⁹ Po	²²⁰ Po	²²¹ Po	²²² Po	²²³ Po	²²⁴ Po	²²⁵ Po	²²⁶ Po	²²⁷ Po				
Bismuth Z=83	²¹² Bi	²¹³ Bi	²¹⁴ Bi	²¹⁵ Bi	²¹⁶ Bi	²¹⁷ Bi	²¹⁸ Bi	²¹⁹ Bi	²²⁰ Bi	²²¹ Bi	²²² Bi	²²³ Bi	²²⁴ Bi						
Lead Z=82	²¹¹ Pb	²¹² Pb	²¹³ Pb	²¹⁴ Pb	²¹⁵ Pb	²¹⁶ Pb	²¹⁷ Pb	²¹⁸ Pb	²¹⁹ Pb	²²⁰ Pb									
Thallium Z=81	²¹⁰ Tl	²¹¹ Tl	²¹² Tl	²¹³ Tl	²¹⁴ Tl	²¹⁵ Tl	²¹⁶ Tl	²¹⁷ Tl	²¹⁸ Tl										

First results:

- β -decay half-lives for ^{225,226}At,
^{227,229}Rn

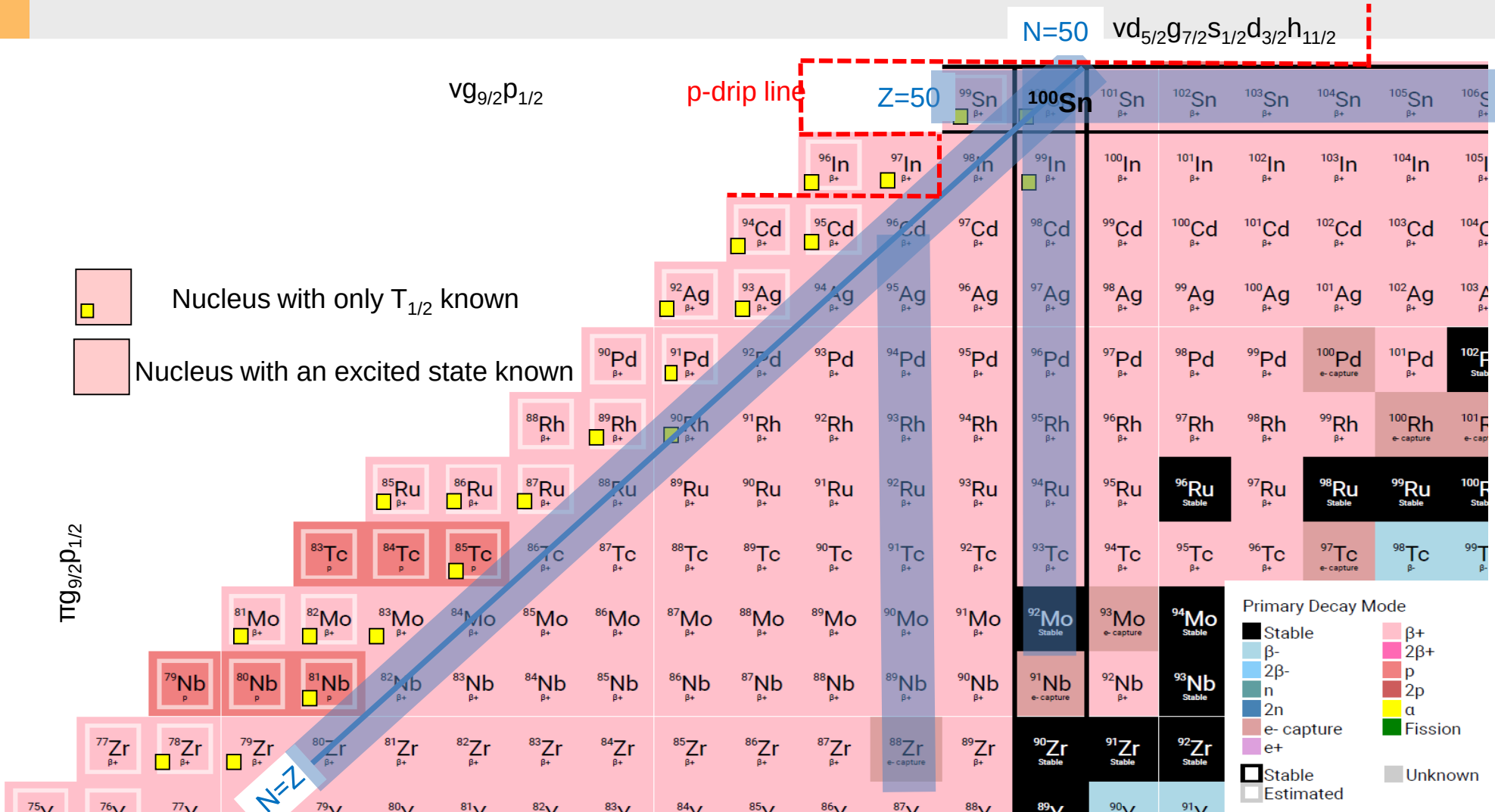
On-going analysis:

- β -delayed γ -ray spectra to find signature of octupole correlation



M. Polettini, G. Benzoni

Nuclear Structure in the ^{100}Sn region



M.G., Physics 2022, 4(1), 364

Shell structure around ^{100}Sn / ^{56}Ni

$L=2$ ($=|I_p - I_n|$) softness
E2 polarisation, isomers

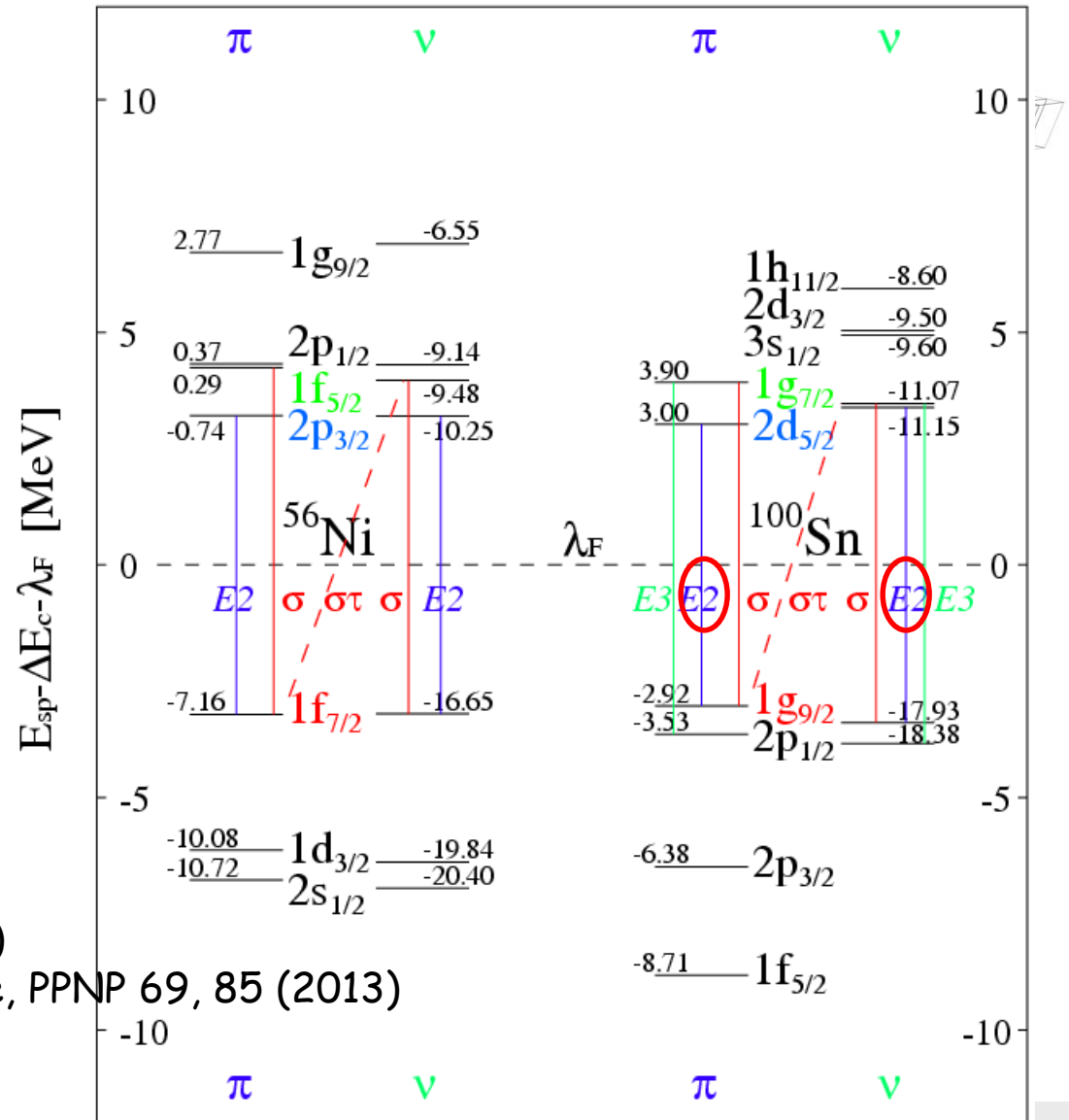
$\sigma/M1$ and $\sigma\tau/GT$ transitions

$L=3$ ($=|I_p \pm I_n|$) E3 collectivity

H. Grawe et al., Phys. Scr. T56,71(95)

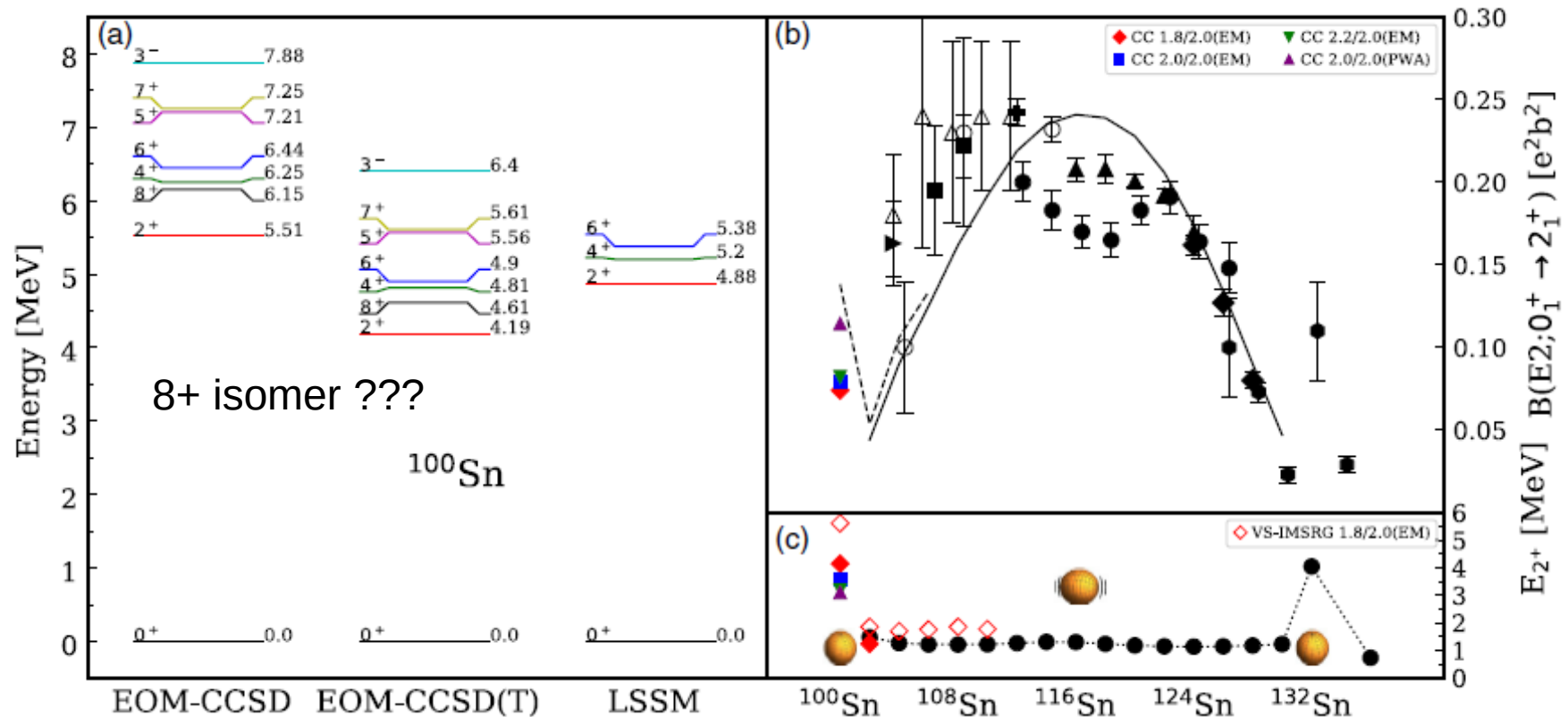
H. Grawe, M. Lewitowicz NPA693,116(01)

updated in T. Faesterman, M.G, H. Grawe, PPNP 69, 85 (2013)



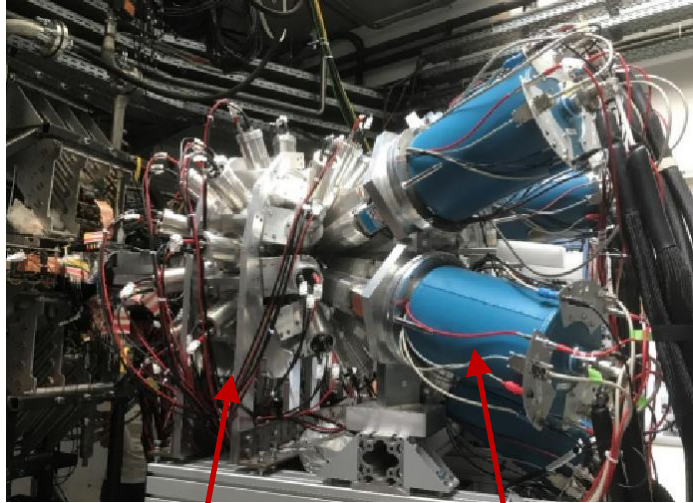
^{100}Sn excited states still not known

- T. D. Morris, Phys. Rev. Lett. **120**, 152503 (2018) ab initio, renormalized equation of motion, incl. 3 body forces, couple cluster method, valence-space in-medium similarity-renormalization-group method (VS-ISMGR)
- K. K. Hebeler, S. K. Bogner, R. J. Furnstahl, A. Nogga, and A. Schwenk, Chiral low-momentum interactions, Phys. Rev. C **83**, 031301 (2011).



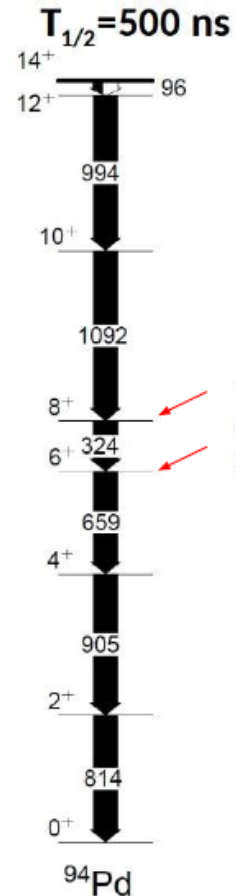
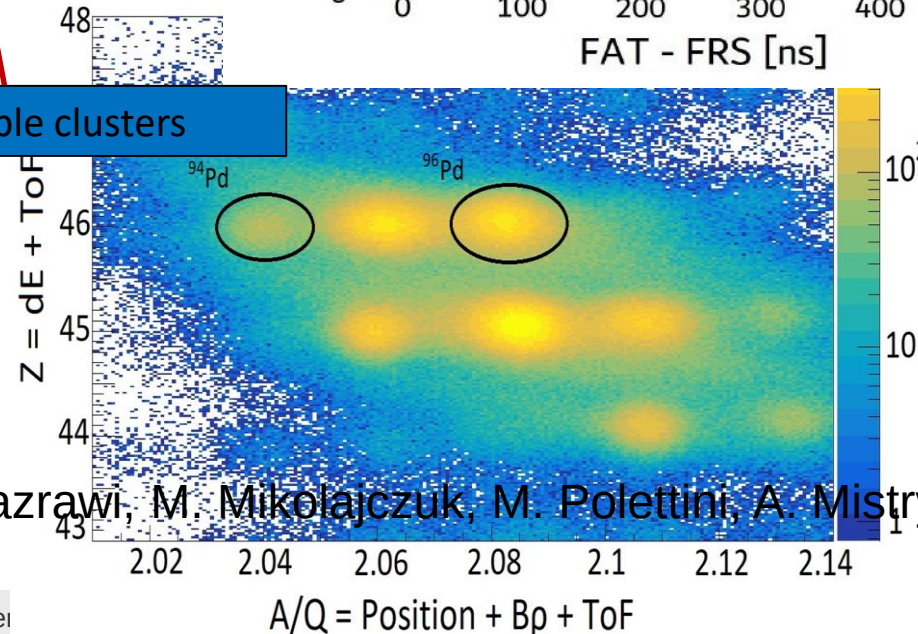
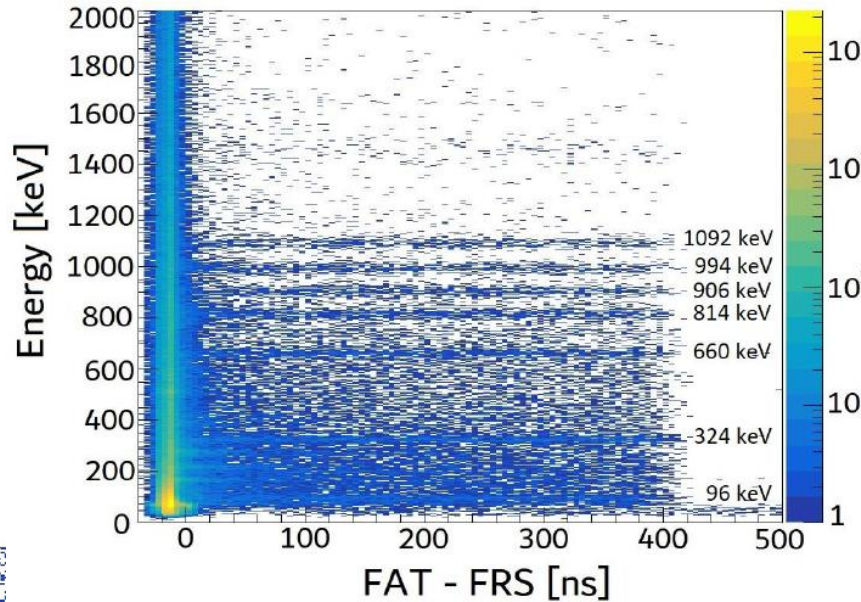
DESPEC 2020: Structure of the heaviest N=Z nuclei: Seniority Transitions and EM Transition Rates in ^{94}Pd

M.G, P. H. Regan, B. Cederwall, J.Jolie



FATIMA modules

HPGe triple clusters



M.Górska, et al., Z.Phys. A353, 233 (1995)
Brock, et al., Phys.Rev. C 82, 061309(R) (2010)

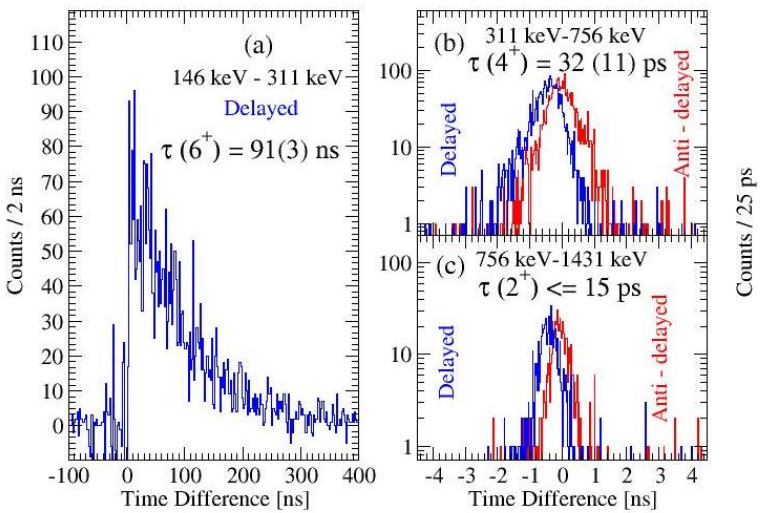
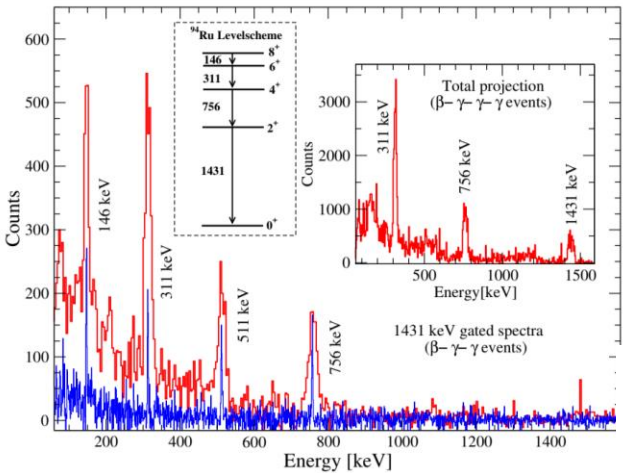
Analysis: A. Yaneva, S. Jazrawi, M. Mikolajczuk, M. Poletini, A. Mistry, H. Albers

First published results from Physics commissioning run

B. Das, B. Cederwall, C. Qi, M. Górska, P.H.Regan et al., Phys. Rev. C 105, L031304(2022).

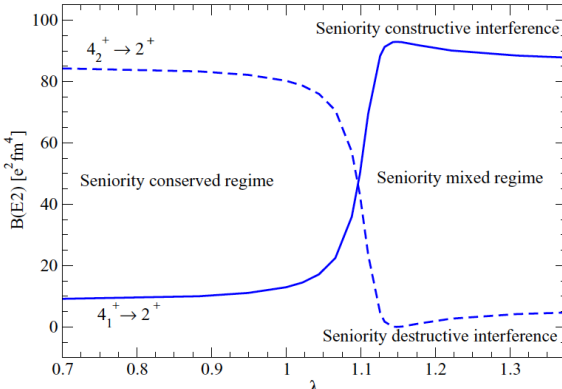


Excited states in ⁹⁴Ru were populated primarily via the β-delayed proton emission of ⁹⁵Pd nuclei



$I_i^\pi \rightarrow I_f^\pi$	τ (ps)	$B_{EX}(E2)$ ($e^2\text{fm}^4$)	$B_{SMLB}(E2)$ ($e^2\text{fm}^4$)	$B_{SDGN}(E2)$ ($e^2\text{fm}^4$)
$8^+ \rightarrow 6^+$	$102(4) \times 10^6$	0.09(1)	2.0	0.77
$6^+ \rightarrow 4^+$	$91(3) \times 10^3$	3.0(2)	6.1	17.3
$4^+ \rightarrow 2^+$	32(11)	103(24)	6.8	85.2
$2^+ \rightarrow 0^+$	≤ 15	≥ 10	225	295

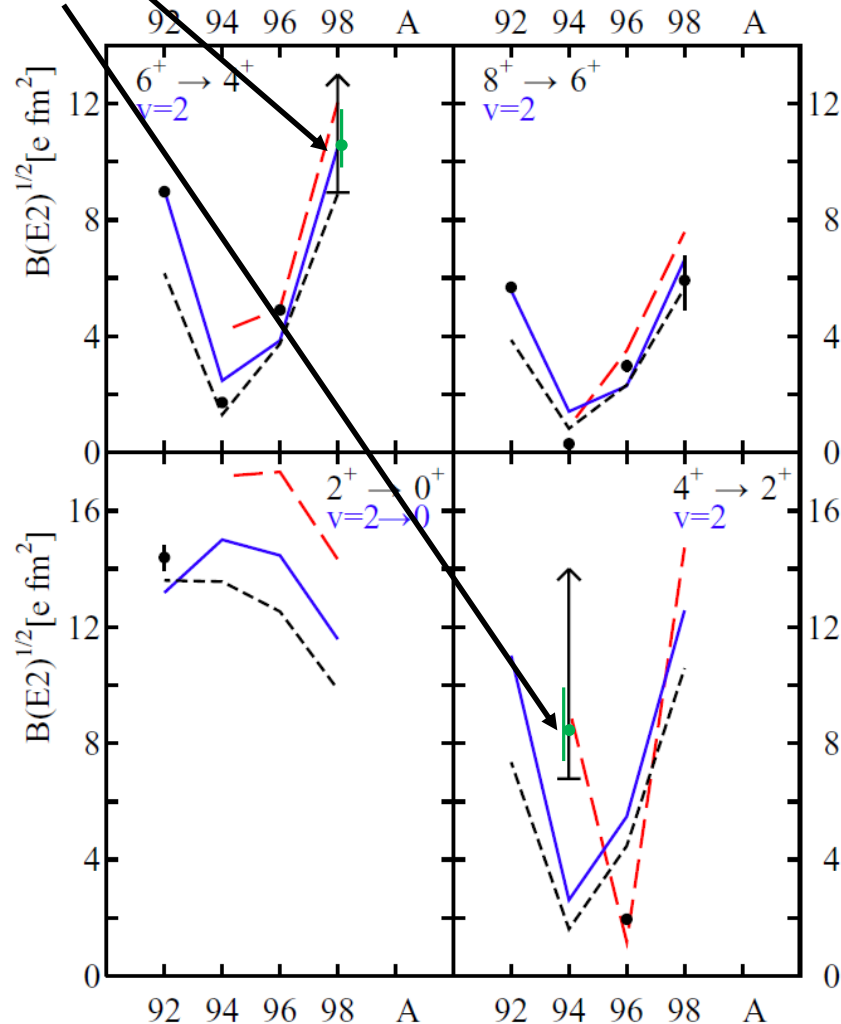
subtle interference between the wave function of the lowest seniority $\nu = 2, J^\pi = 4^+$ state and that of a close-lying $\nu=4$ state that exhibits partial dynamic symmetry



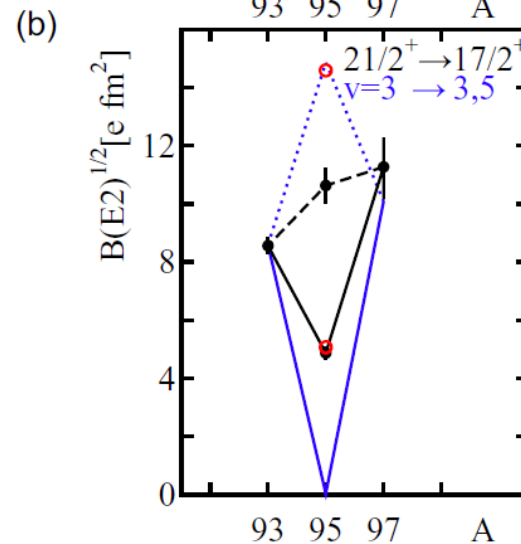
Seniority mixing by core excitation in N=50 ^{96}Pd and ^{94}Ru and ^{98}Cd ?

J. Park et al., Phys. Rev. C **96**, 044311 (2017)

B. Das et al., Phys. Rev. C **105**, L031304 (2022)



H. Mach et al., Phys. Rev. C **95**, 014313 (2017)



$\pi g_{9/2}^n$, $n=5$,
midshell:

• No mixing in π
space

• $B(E2; \Delta v=0) \equiv 0$

Seniority v :

• Neutron core
excitation breaks
good seniority

+ New data analysis on ^{95}Rh : B. Das et. al.

-- SDG: F. Nowacki

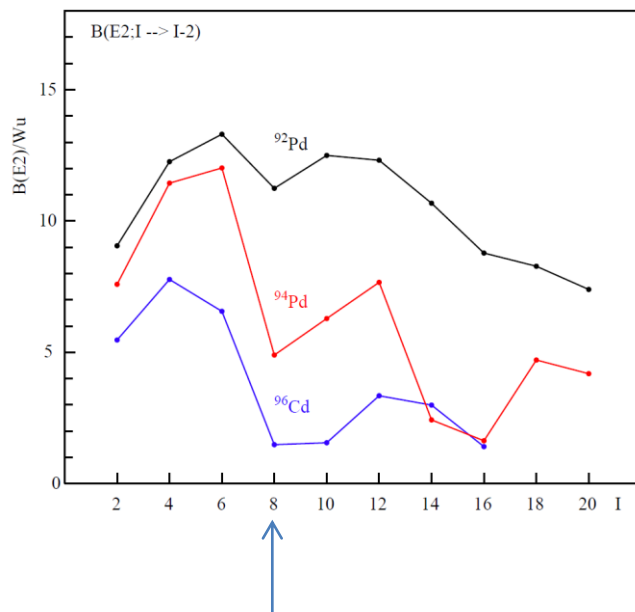
— SMLB: A. F. Lisetskiy, B. A. Brown, M. Horoi,
and H. Grawe, Phys. Rev. C **70**, 044314 (2004).

..... SMCC: L. Coraggio, A. Covello, A. Gargano, and
N. Itaco, Phys. Rev. C **85**, 034335 (2012)

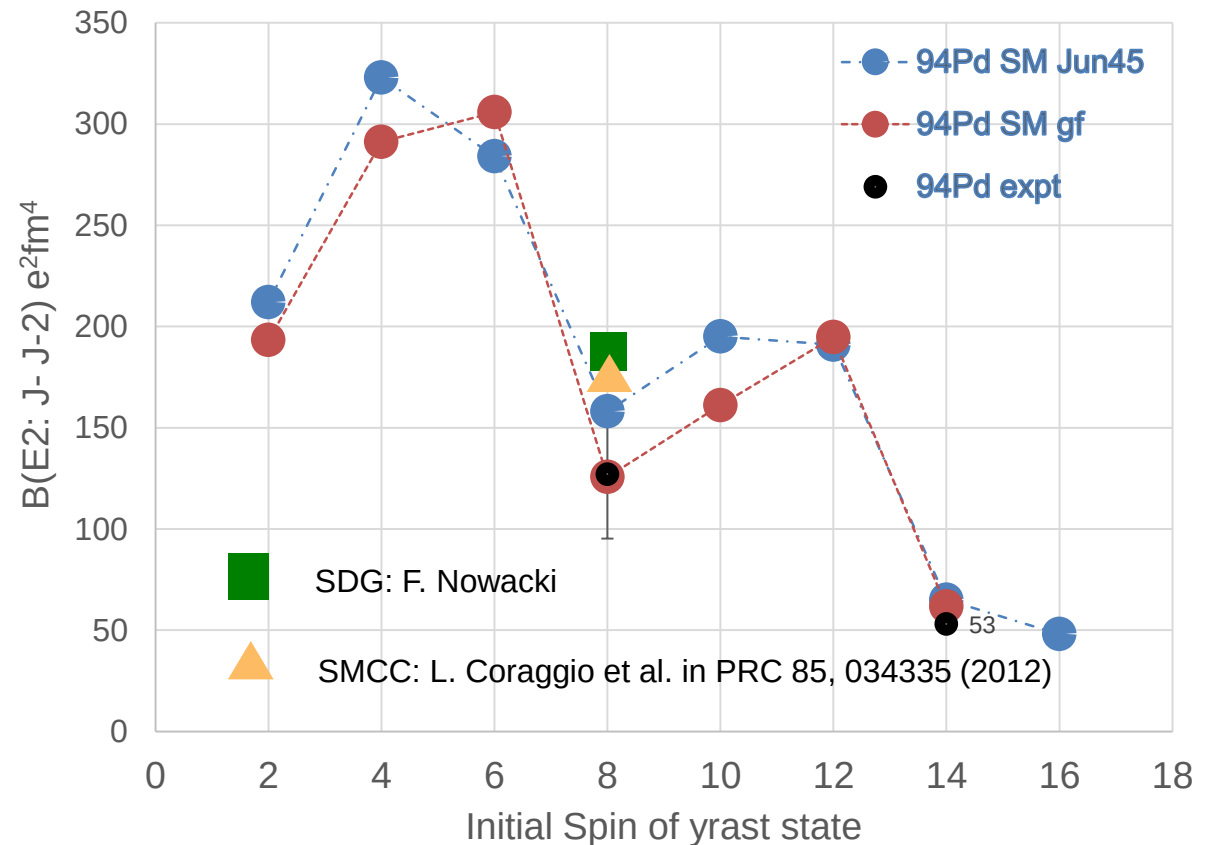
^{94}Pd $B(E2:8+ \rightarrow 6+)$

provides a stringent test for the various models SM, B-pair and model spaces
g9, f5pg9, gds

GF predictions



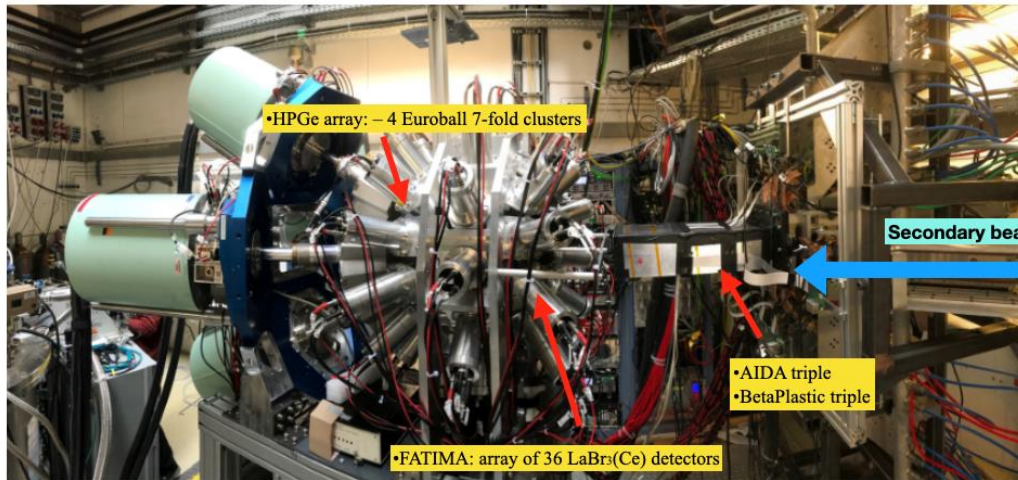
^{94}Pd SM and expt comparison.



Analysis: A. Yaneva, S. Jazrawi

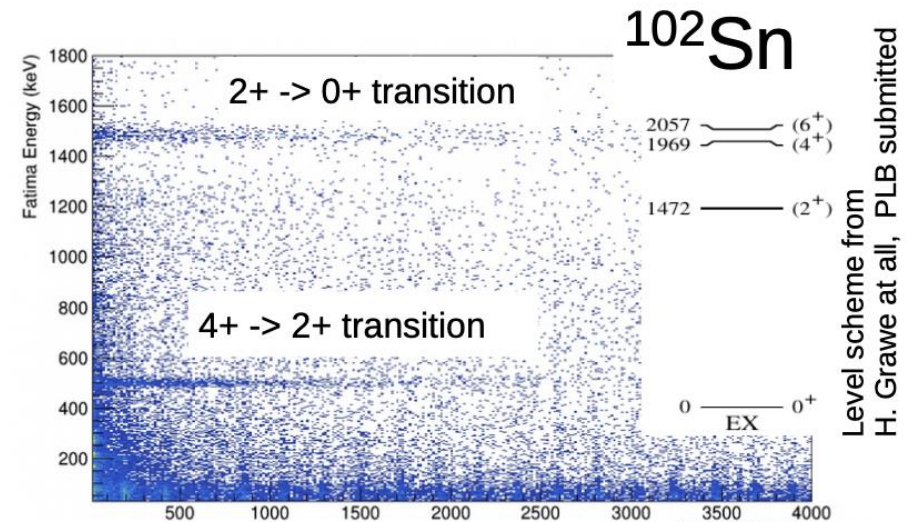
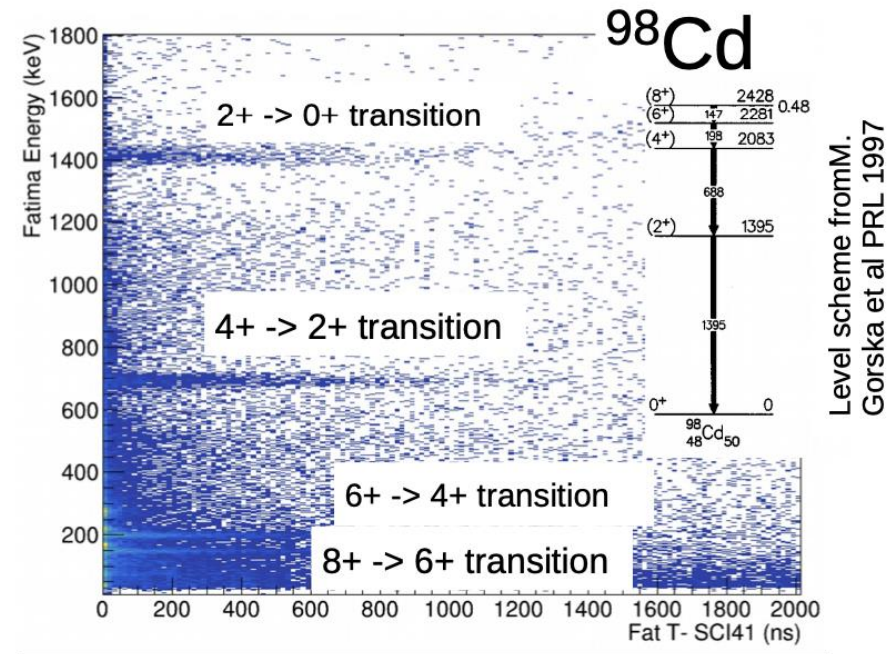
Calculation: GF and JUN45: M. Mikolajczuk

DESPEC 2021: Core-breaking in the most neutron-deficient Tin isotopes

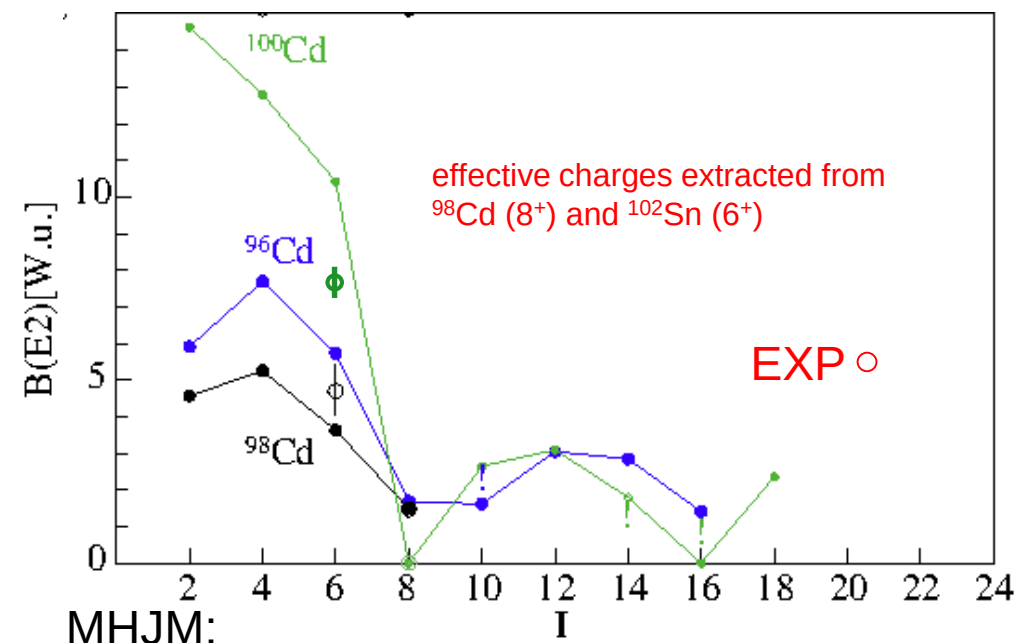


- Experiment: ^{124}Xe beam (2×10^9 pps, 840 MeV/u) + 6.333 g/cm² ^9Be Target,
- Ion of interest: ^{102}Sn , ^{107}Te , $^{98,100}\text{Cd}$
- DESPEC station: Triple-AIDA+ Triple-BetaPlastic + 4 Euroball 7-folded clusters + FATIMA,
- Result: lifetimes of 4^+ states in ^{102}Sn , $^{98,100}\text{Cd}$ is measured for the first time, preparing for publication now.

G. Zhang, D. Mengoni

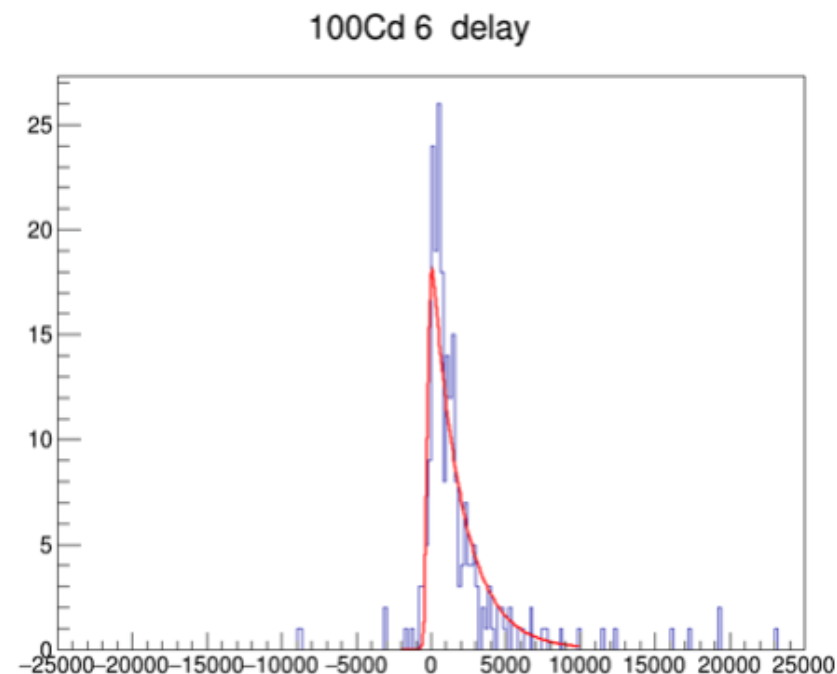


^{100}Cd anomaly



MHJM:

Kavatsyuk O, et al., 2007 *Eur. Phys. J. A* **31**(3) 319, and Blazhev A, Górska M, Grawe H in preparation



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

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

G. Zhang, D. Mengoni

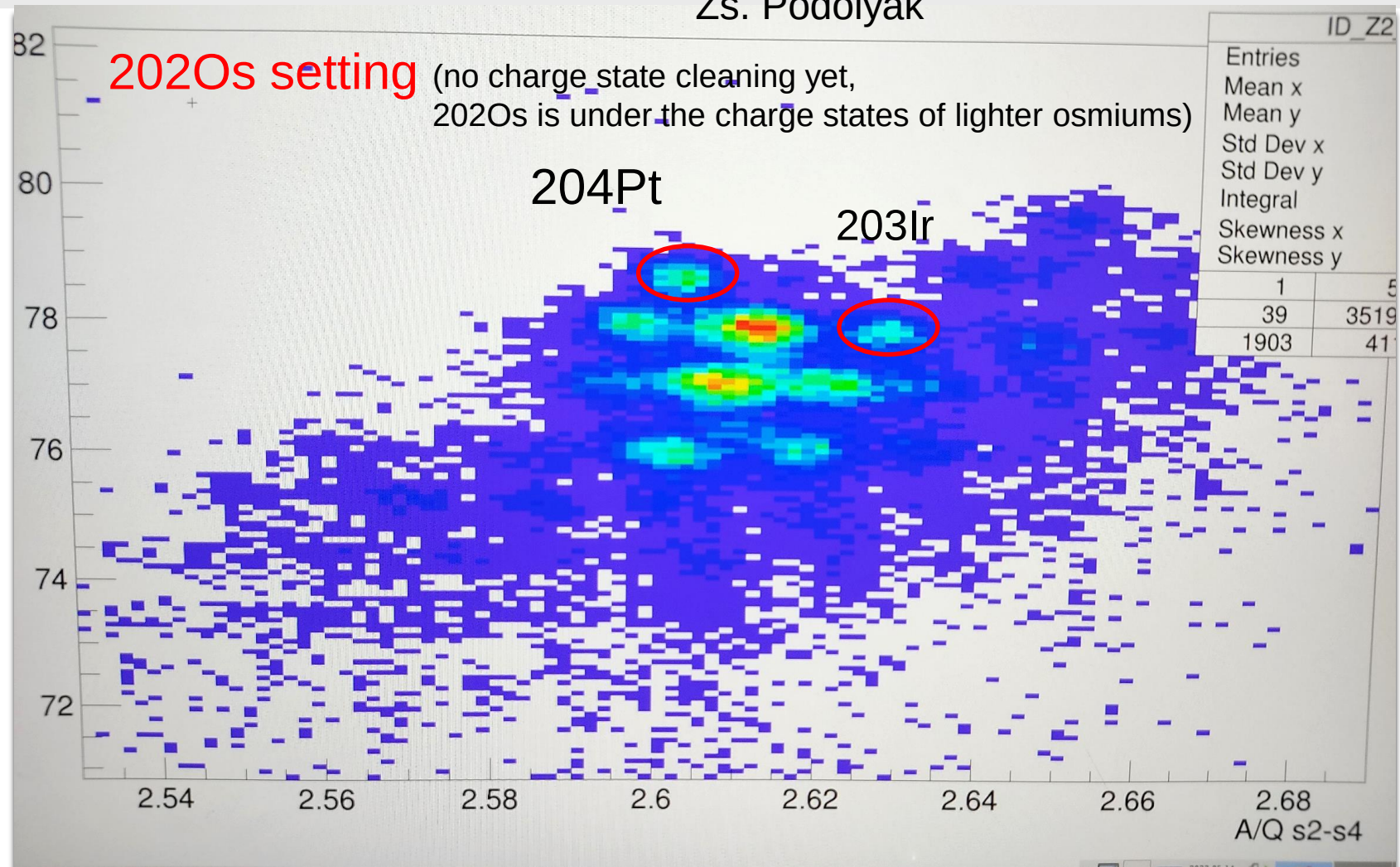
DESPEC 2022: Mounting of DEGAS in a record short time!



S450: Study of N=126 nuclei:
Isomeric and beta decays in ^{202}Os and ^{203}Ir

May 2022

Zs. Podolyak



^{203}Ir spectrum

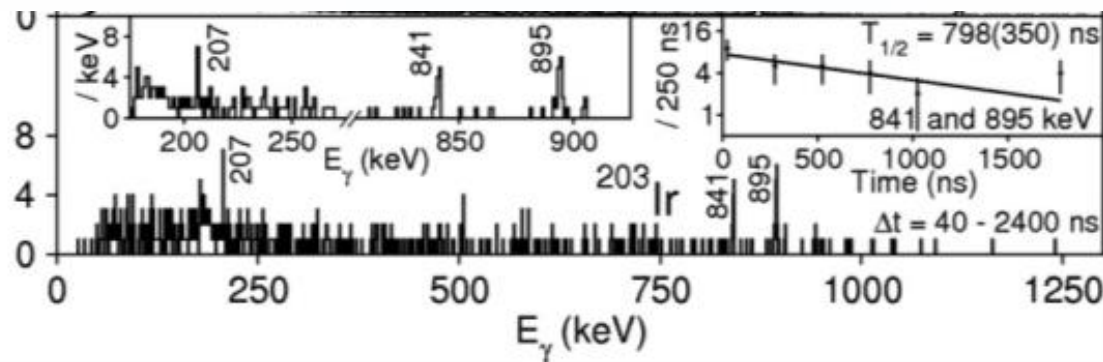
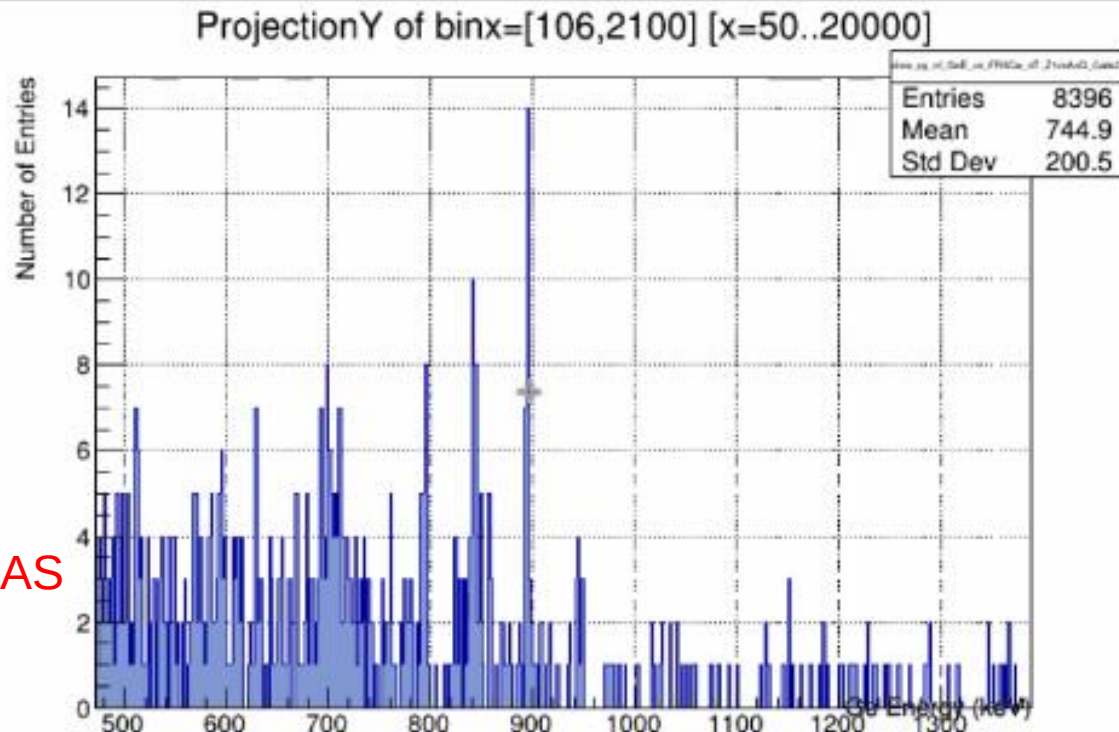
New, measured in 2022

(higher statistics than in 2006)

- DEGAS Ge array used for the first time
- Efficiency was lower than for the final DEGAS
- Beam intensity increased about one day before the end of experiment

Old, measured in 2006

Zs. Podolyak



DTAS @ DESPEC

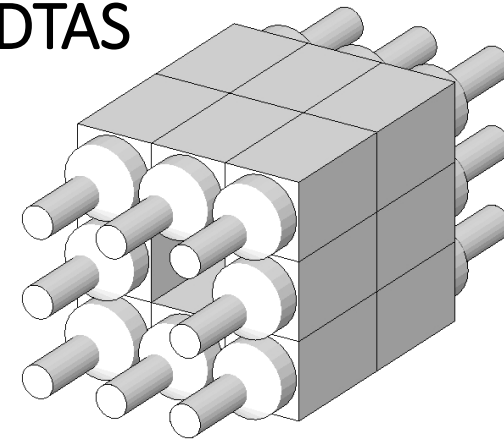


β -strength measurements to understand
 β half-life discrepancies **across N=126**



Total Absorption Gamma-ray
Spectroscopy (TAGS)

DTAS



First experiment
JUNE 2022

		207Hg 2.9m 4.6MeV (9/2+)
204Au 39.8s 4.0MeV (2-)	205,205mAu 32.5/6s 3.5/4.4MeV (3/2+, 11/2-)	206Au 45s 6.7MeV (?)
203,203mPt 22s/12s 3.5MeV (1/2-, ?)	204Pt 16s 2.7MeV 0+	

S505

Investigation of the beta strength crossing $N=126$ and the formation of the 3rd r -process abundance peak

Primary beam: ^{208}Pb

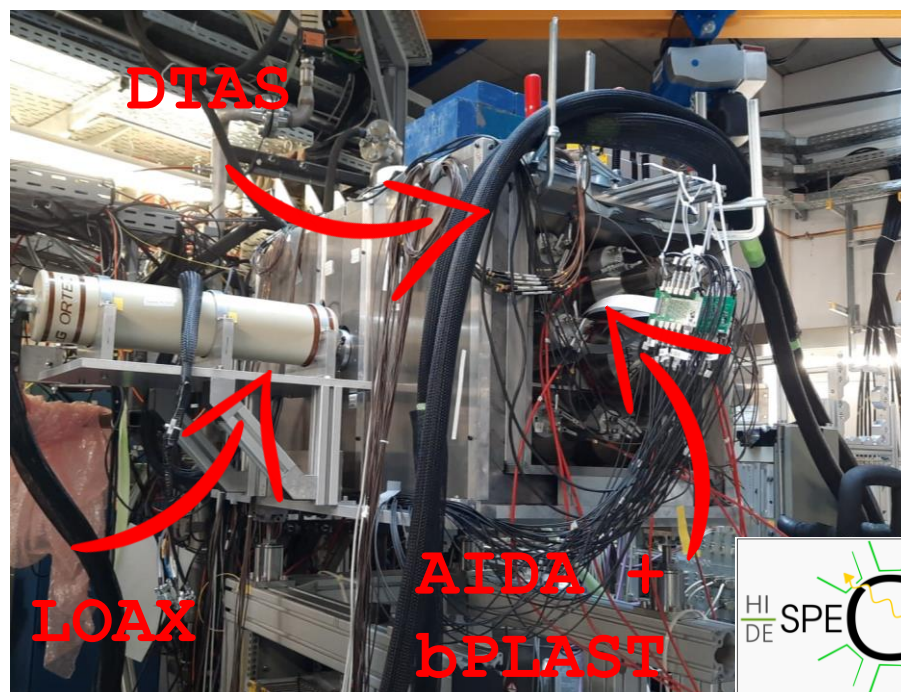
Energy: **1000 MeV/u**

Intensity: **10^9 ppb**

Pulse: **1.6 s**

Spokespersons: **J.L. Tain, A.I. Morales, E. Nacher**

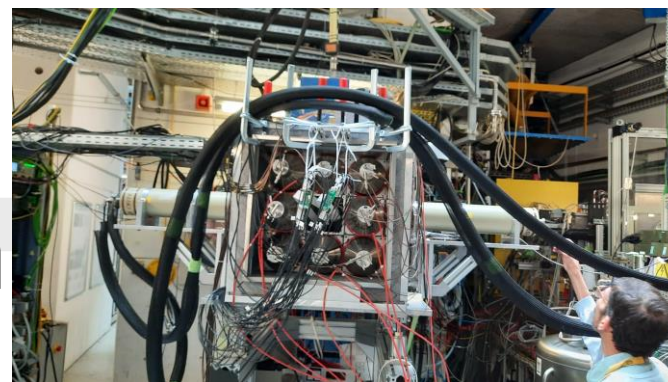
- ➔ First full beta-strength measurement of neutron-rich nuclei around $N=126$
- ➔ Study of decay properties of nuclei leading to the formation of the “gold” peak in explosive stellar nucleosynthesis



DTAS gamma-calorimeter and narrow AIDA implant-decay detector of the DESPEC experiment



S505 preparation

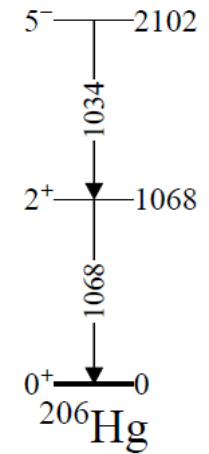
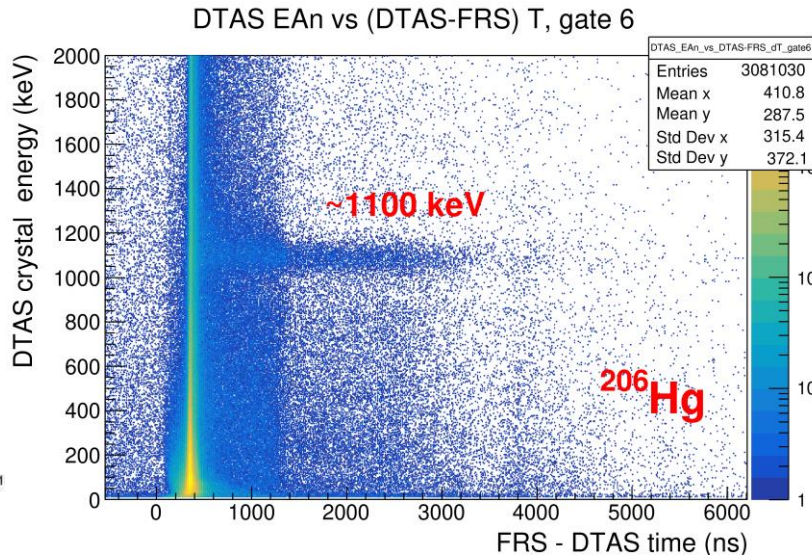
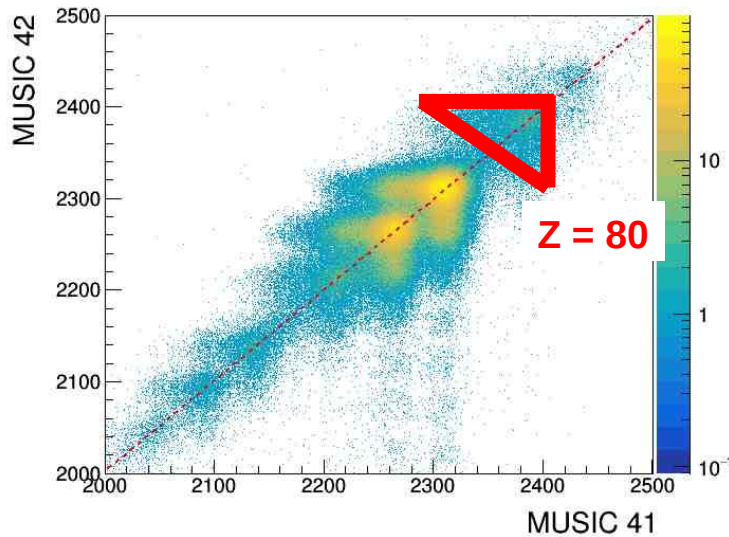


		207Hg 2.9m 4.6MeV (9/2+)
204Au 39.8s 4.0MeV (2-)	205,205mAu 32.5/6s 3.5/4.4MeV (3/2+, 11/2-)	206Au 45s 6.7MeV (?)
203,203mPt 22s/12s 3.5MeV (1/2-, ?)	204Pt 16s 2.7MeV 0+	

S505 Online

PRELIMINARY

Isomer tagging. The 5^- isomer in ^{206}Hg



		207Hg 2.9m 4.6MeV (9/2+)
204Au 39.8s 4.0MeV (2-)	205,205mAu 32.5/6s 3.5/4.4MeV (3/2+, 11/2-)	206Au 45s 6.7MeV (?)
203,203mPt 22s/12s 3.5MeV (1/2-, ?)	204Pt 16s 2.7MeV 0+	

S505 Online

TAGS Spectra

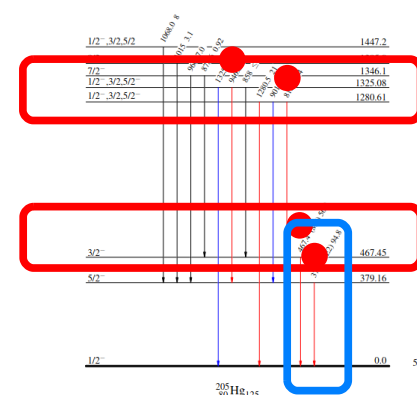
PRELIMINARY

²⁰⁵Au decay

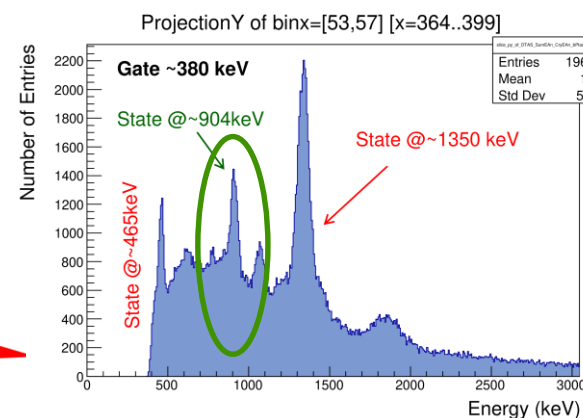
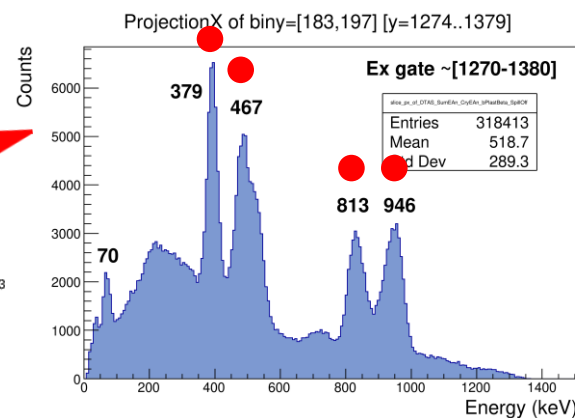
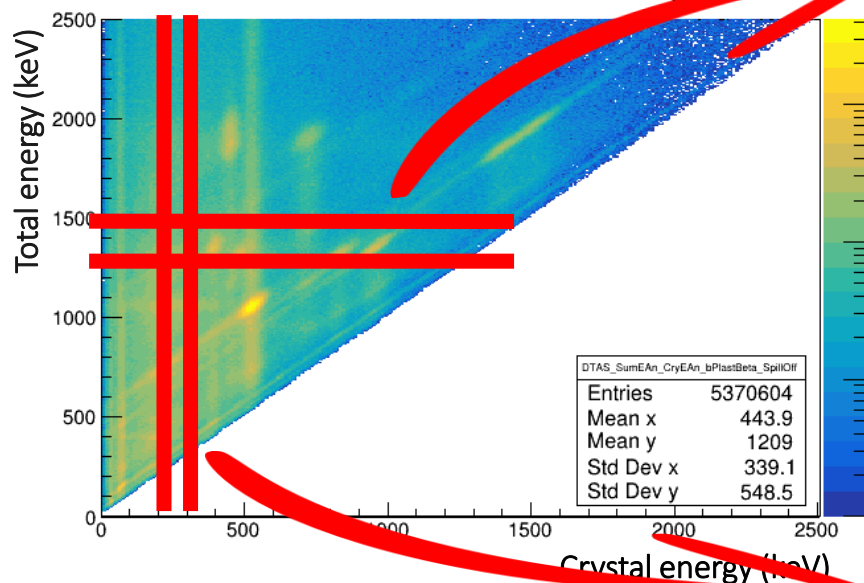
— Au p decay 1994W02, 2001P001, 2010F02A

Decay Scheme
Intensities: Relative I_γ

Legend
I_γ < 25% I_γ^{max}
I_γ < 10% I_γ^{max}
I_γ > 10% I_γ^{max}



DTAS-bPlast coincidences OffSpill

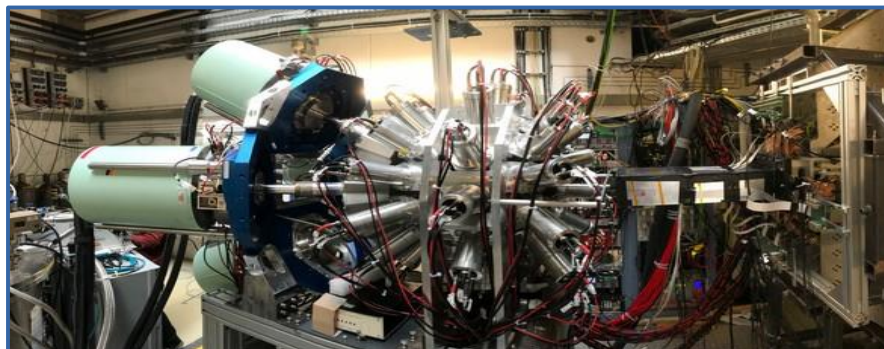


DEGAS: Plans for the near future

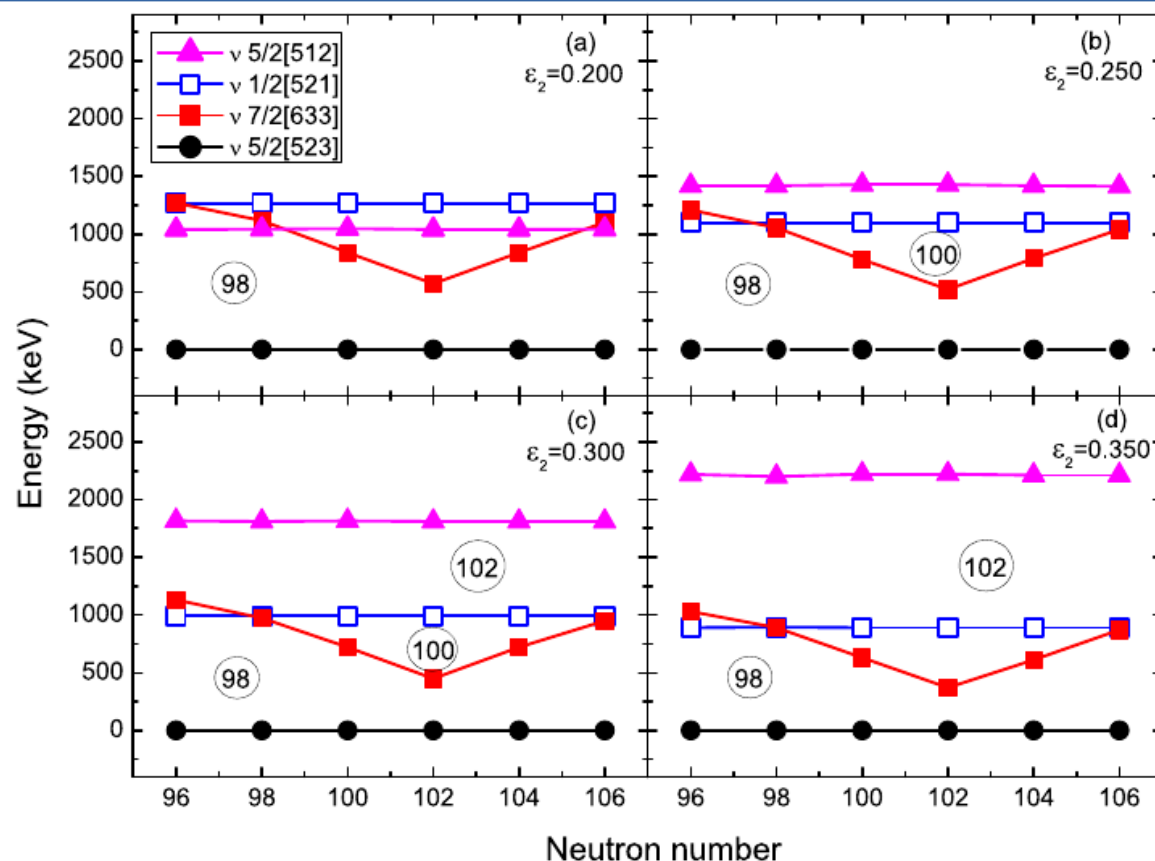
Strong interest in the FATIMA/DEGAS setup:

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:** High-energy beams of ^{170}Er increasing the cross section



- Recent PSM calculations indicate
- *modified Nilsson parametrisation*
- needed for correct SP ordering
- Location and size of deformed shell
- gaps *highly-dependent on N and deformation parameter*
- *deformation parameter*
- Effect of $\nu 7/2[633]$ most apparent at
- $N=98-104$



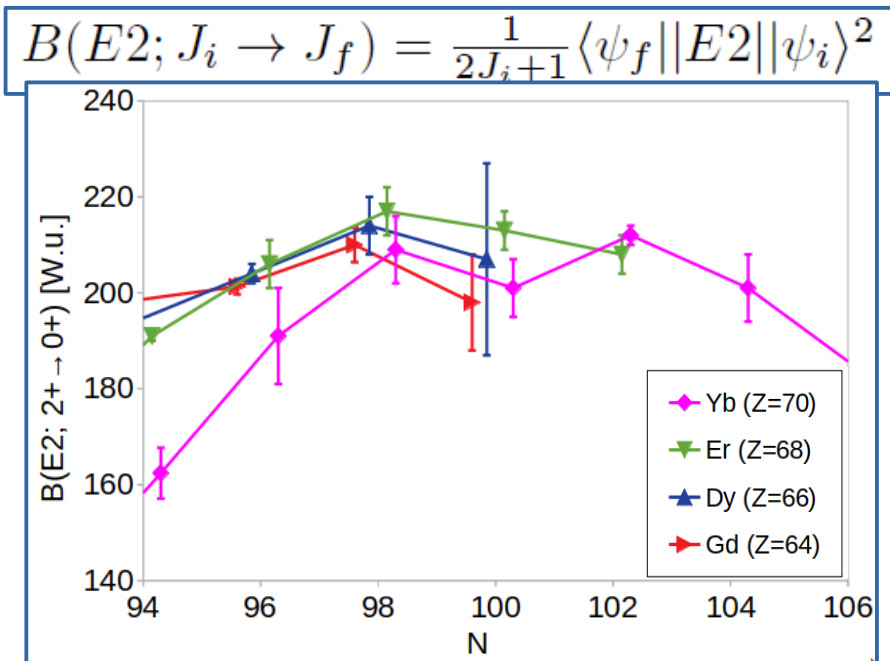
Decay properties of $^{160,162}\text{Eu}$ at ANL $\rightarrow$ deformed shell gap at $N=98$

D.J. Hartley *et al.*, PRL **120**, 182502 (2018)

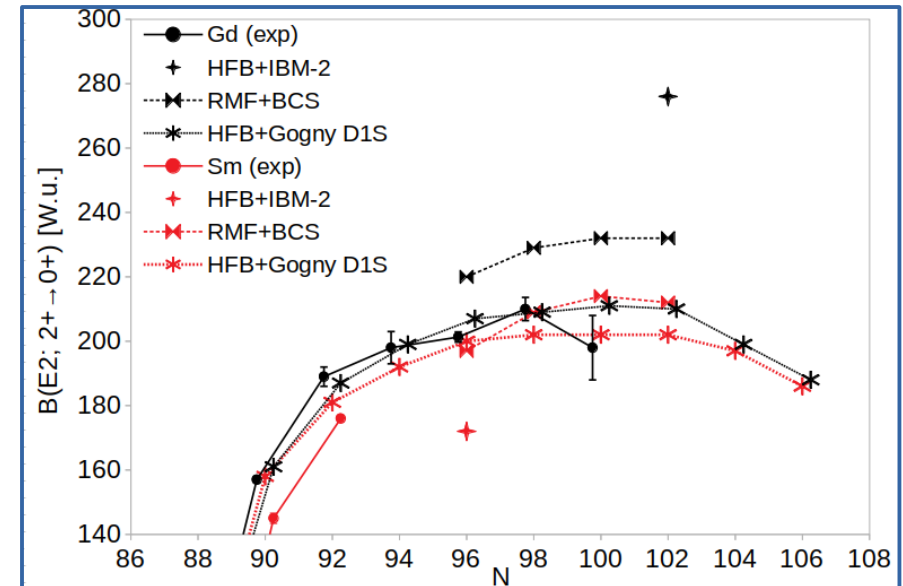
Structure of neutron-rich rare earth nuclei

Scientific Motivation

- Region of **highly-deformed rare-earth nuclei** close to the mid-mid-shell are a subject of great interest for both nuclear structure and astrophysics
- Open questions** regarding location and nature of deformed shell gaps



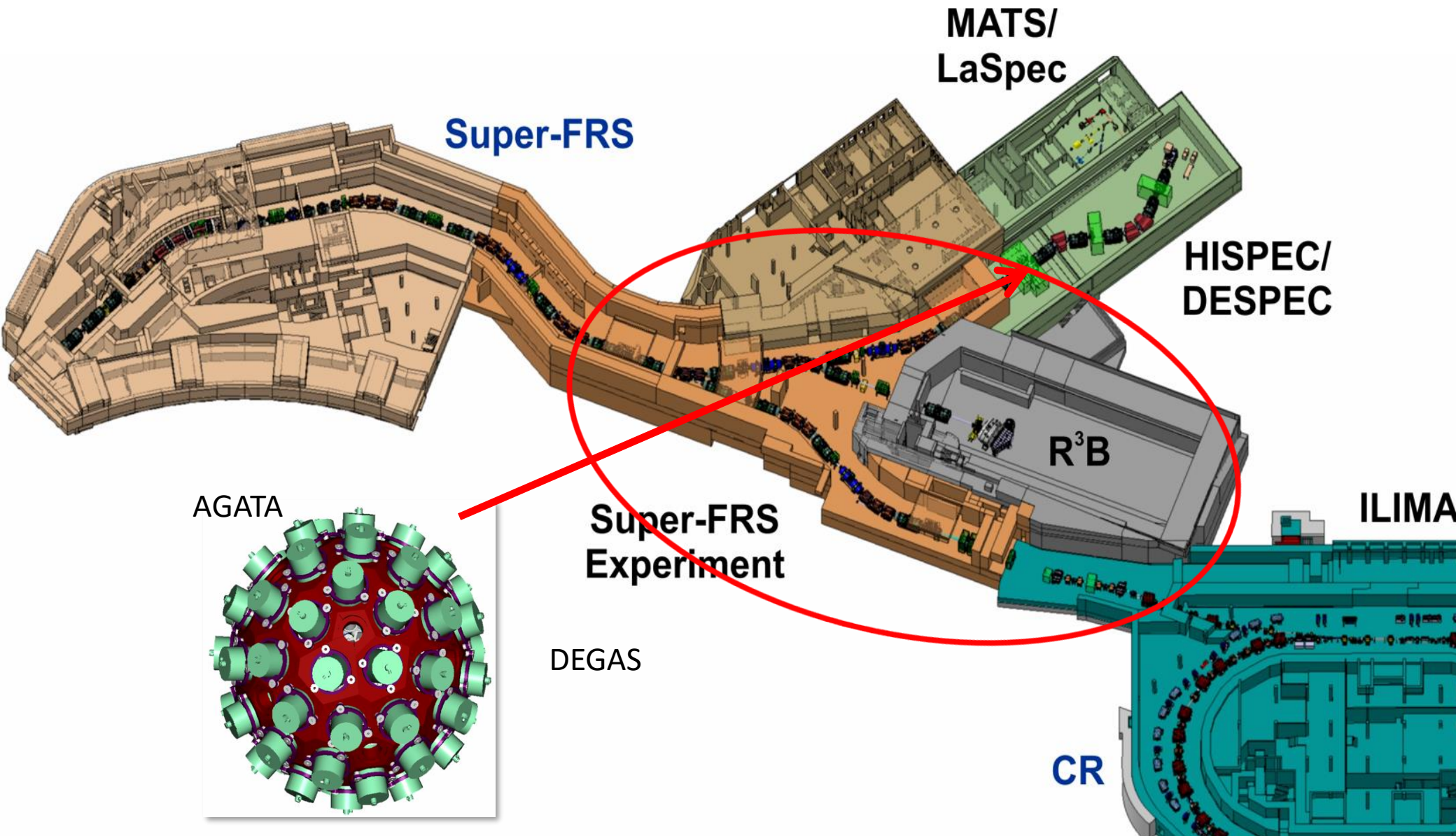
- Large uncertainties or missing data for
- N>98 in Gd and Dy



- HFB+IBM-2 (K. Nomura),
- RMF+BCS (Z.P. Li),
- HFB+Gogny D1S (L. Robledo)

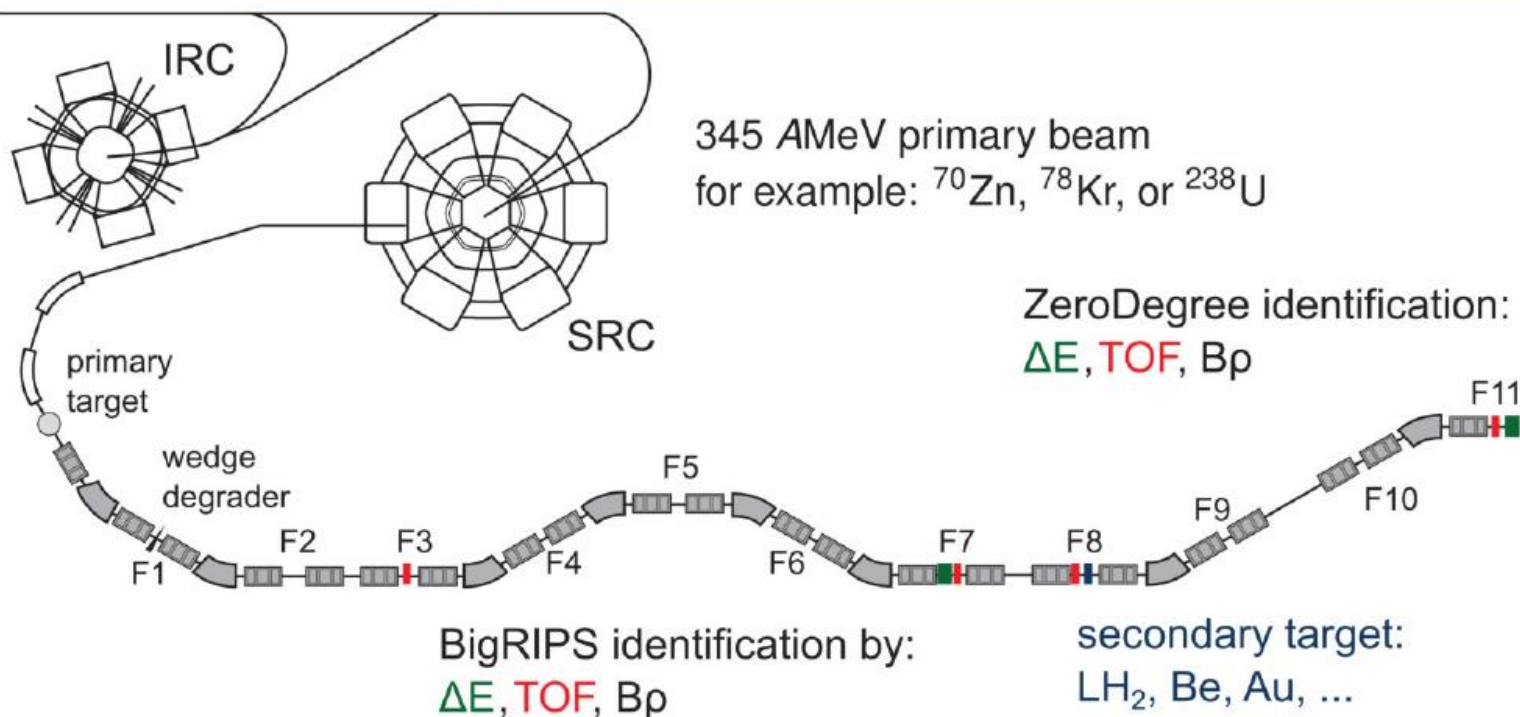
- Smooth changes with N,
- broad **peak before midshell**

HISPEC: High-resolution in-flight γ -ray spectroscopy following secondary nuclear reactions induced by radioactive ion beams at $E \sim 100$ MeV/u to 1 GeV/u and decay spectroscopy

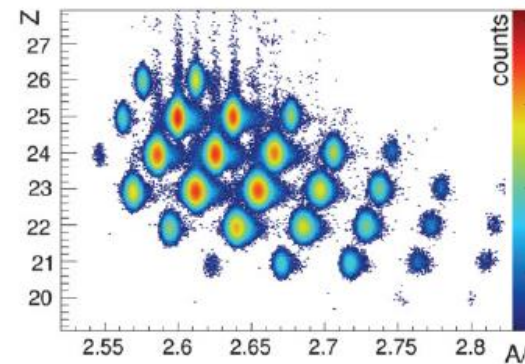


HISPEC: Physics example from RIBF

Beam production and identification



- fragmentation or fission of intense primary beam
- particle identification by $B\rho - \Delta E - \text{TOF}$
- secondary target surrounded by γ -ray detectors
- identification after target:
ZeroDegree or SAMURAI spectrometer

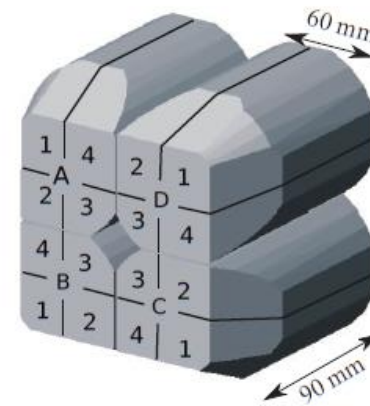
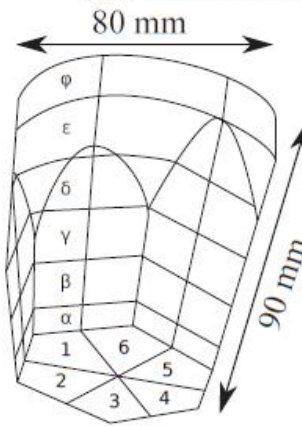
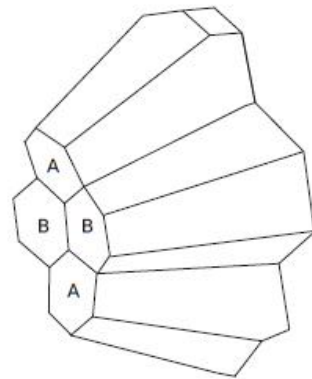
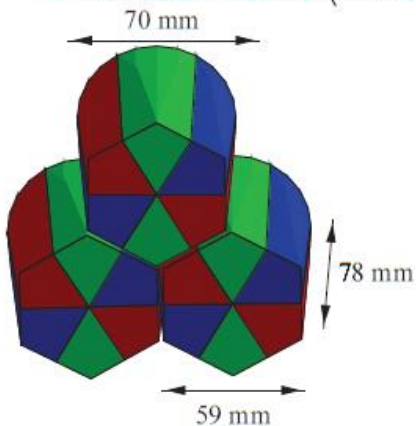
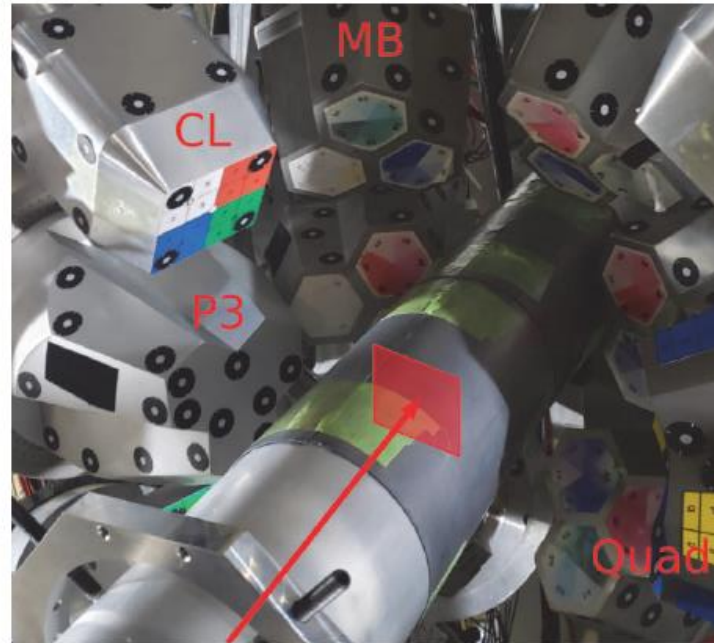


spokespersons: P. Doornenbal and K. Wimmer

HISPEC: Physics example from RIBF

- 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

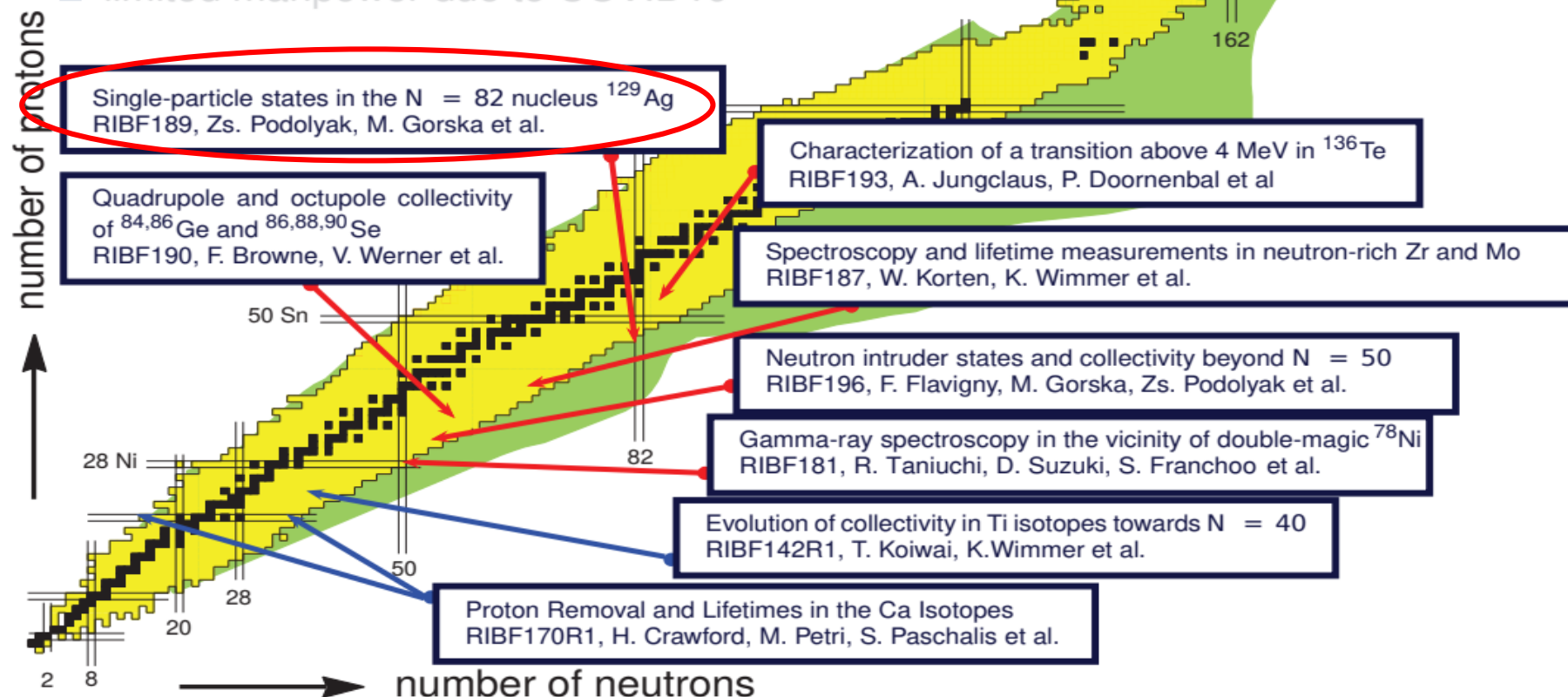
Courtesy: K. Wimmer

HISPEC TYPE: Physics goals example from RIBFAIR



HiCARI campaign

- initially planned for spring 2020, Japan declared state of emergency → postponed
- Nov./Dec. 2020: 7 experiments with ^{238}U (17 d) and ^{70}Zn (7.5 d)
- April 2021: 1 experiment ^{238}U (7 d) primary beam
- limited manpower due to COVID19



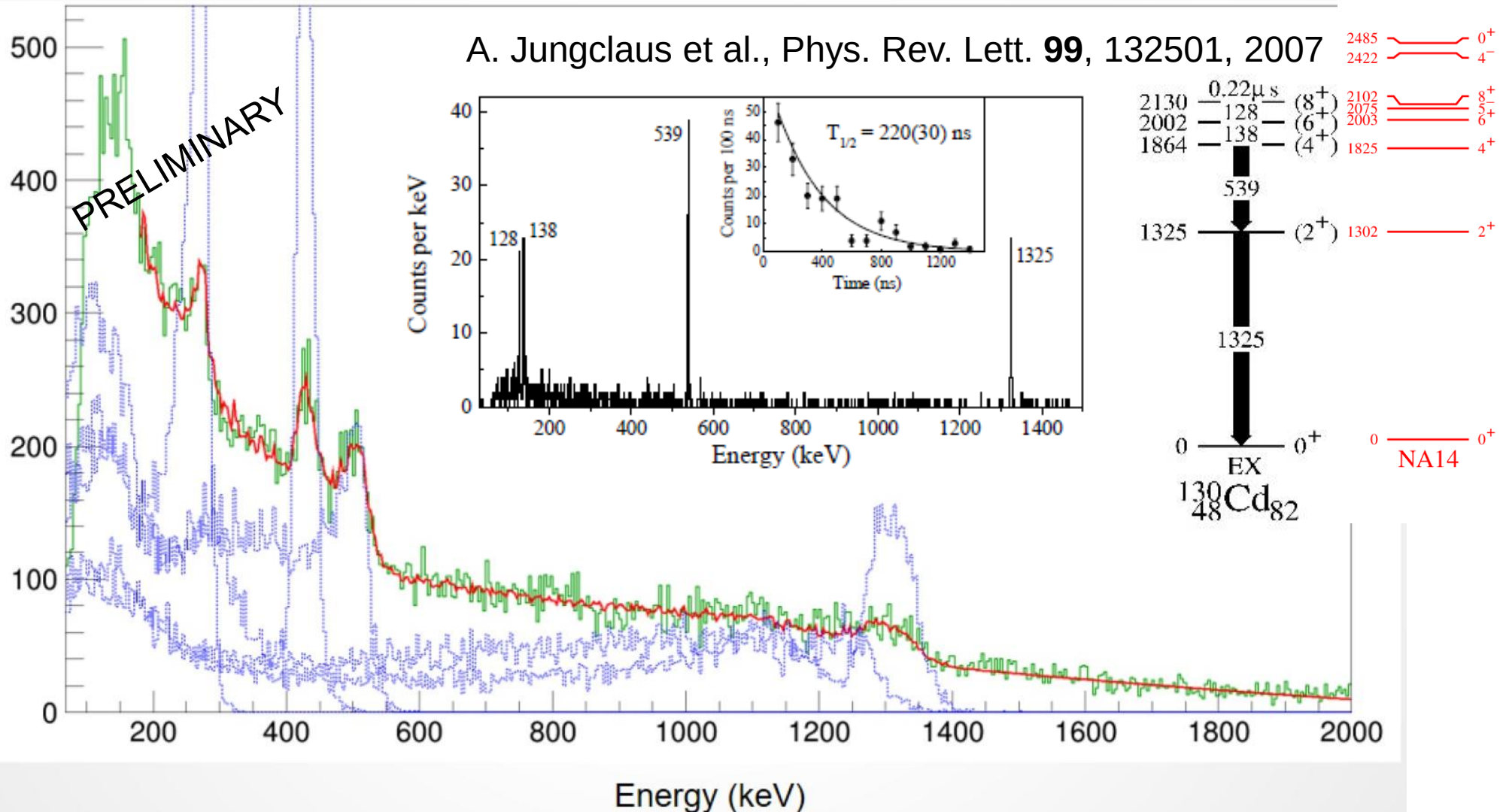
slide by F. Browne

spokespersons: P. Doornenbal and K. Wimmer

HISPEC TYPE: HICARI campaign

Single proton knockout to ^{130}Cd

spokespersons: P. Doornenbal and K. Wimmer



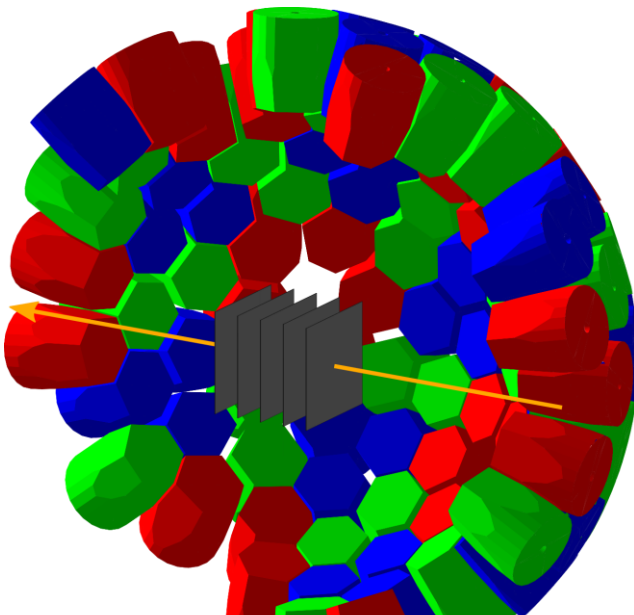
Analysis: Tom Parry (U. of Surrey), Michael Armstrong (GSI/U. Cologne), Zs. Podolyak, M.G.

LISA: Lifetime measurements with Solid Active targets

PI: K. Wimmer



The **coexistence of single-particle and collective degrees** of freedom in atomic nuclei gives rise to various exotic phenomena. Where and how collectivity emerges from the single-particle dynamics of protons and neutrons is an **open question in nuclear structure physics** that will be addressed with LISA in a unique way.

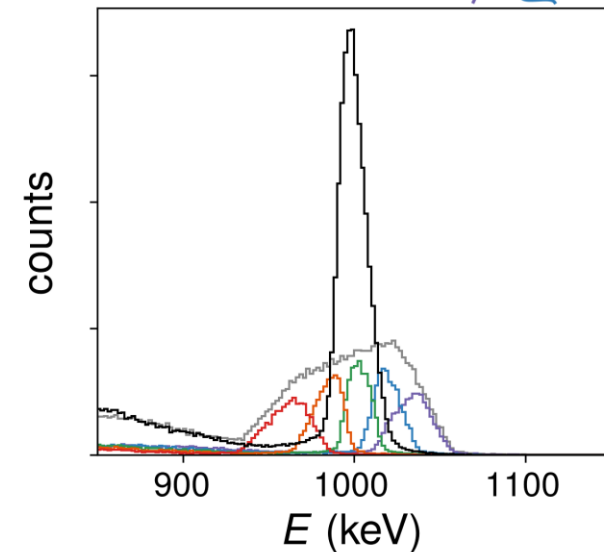
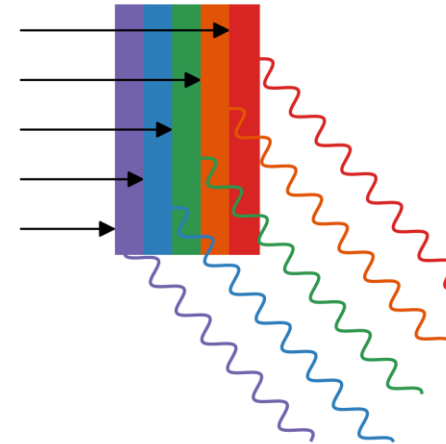


Compact array of active target detectors inside AGATA

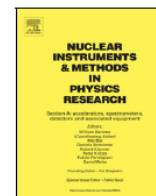
- Energy resolution determined by unknown velocity in the target
- Several layers of active targets
- Event-by-event determination of reaction position $\rightarrow (\beta, z)$

Opens new possibilities for lifetime measurements using AGATA at FAIR:

- Evolution of collectivity in Islands of Inversion
- Fate of the N=82 and 126 shell closures
- And many more



- HISPEC/DESPEC international collaboration to investigate the structure of exotic nuclei
- Several DESPEC experiments produced the first results, many in preparation
- Flexible concept needed to optimize the physics outcome from available infrastructure as stated in the review 2022 comments
- best considered DESPEC setup for early/first physics and discovery potential for many exotic nuclei
 - flexible in its simplest configuration
 - more space demanding in the full configuration including neutron detectors
- Most challenging and relying on the strong collaboration: HISPEC
 - AGATA accommodation
 - Magnetic analyzer of the reaction products



The DESPEC setup for GSI and FAIR

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