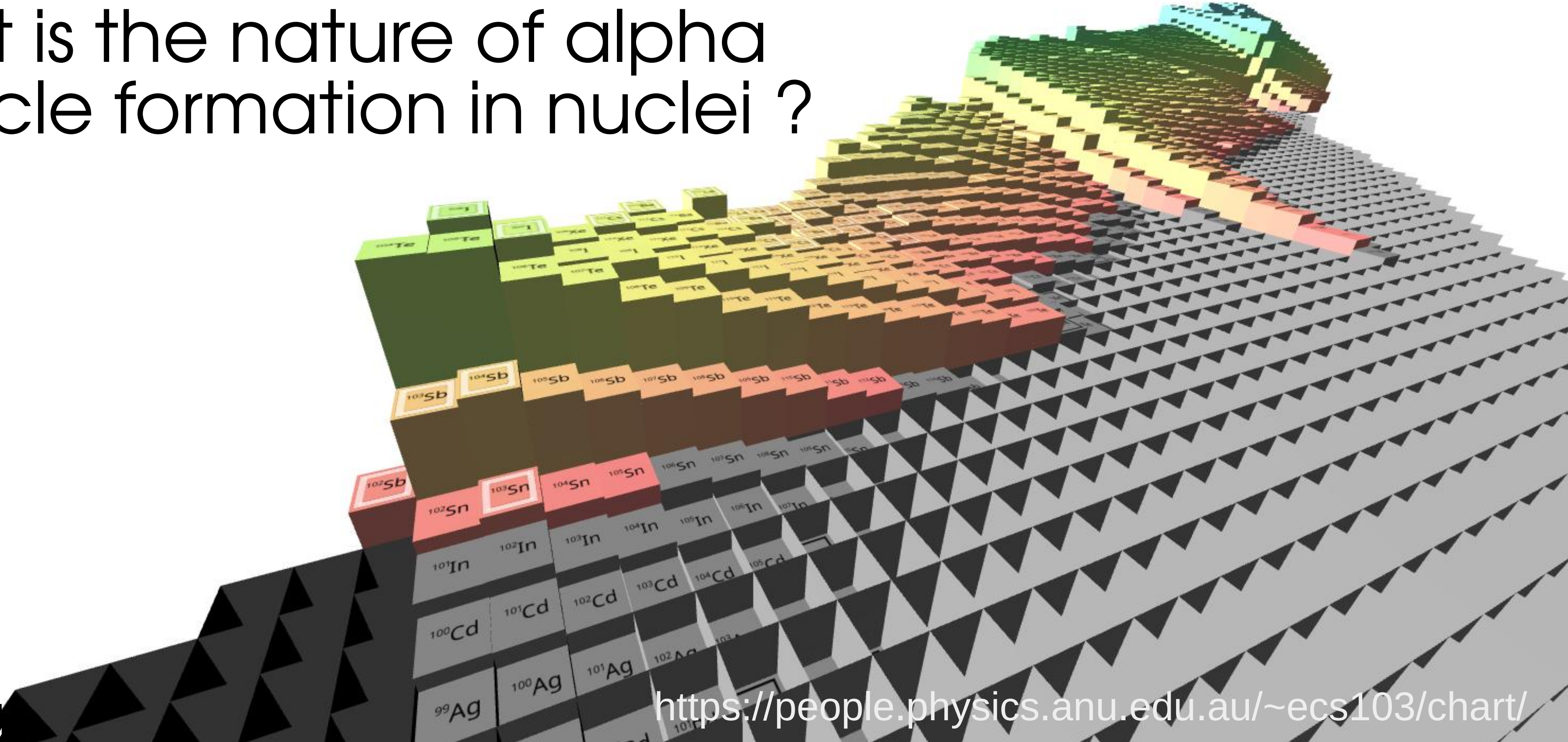
On the birth of an alpha particle

Robert Grzywacz
University of Tennessee

What is the nature of alpha particle formation in nuclei ?



https://people.physics.anu.edu.au/~ecs103/chart/

2016: FRIB SAC endorses Decay Station

FRIB Scientific Advisory Committee meets on FRIB experimental equipment

The FRIB Scientific Advisory Committee (SAC) met on March 2-3, 2015 to discuss the status of plans for experimental equipment at FRIB and on plans for reaccelerated beams and possible future upgrades. The committee is comprised of David Dean (ORNL, Chair), Ani Aprahamian (Notre Dame), Rolf Ent (JLab), Katherine Grzywacz-Jones (Univ. of Tennessee), Robert Janssens (ANL), Augusto Macchiavelli (LBNL), Gail McLaughlin (North Carolina State Univ.), Witek Nazarewicz (Michigan State Univ.), and Michael Smith (ORNL, Ex-Officio representing the FRIB Users Organization). Thomas Glassmacher gave the SAC an update on the status of FRIB, Michael Smith gave a presentation on the current status of plans for various experimental systems proposed for FRIB, and Alexandra Gade described current plans and the physics reach of reaccelerated beams and possible future upgrade paths. The recommendations of the SAC on the status and priority of the different projects will be sent to the new Director of the FRIB Laboratory, Thomas Glasmacher.

2015

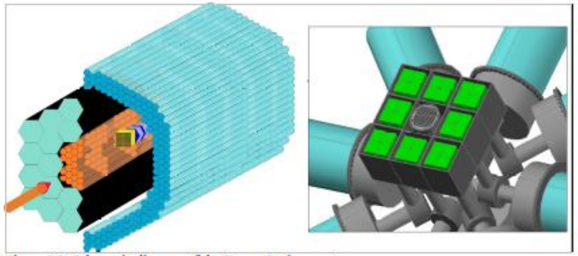
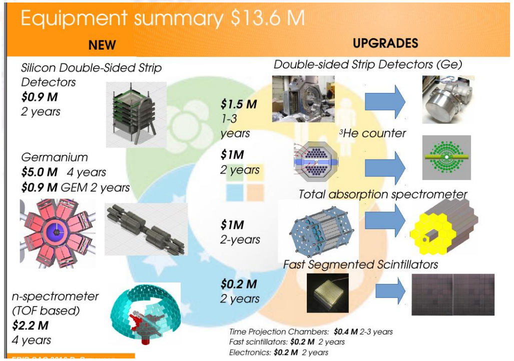
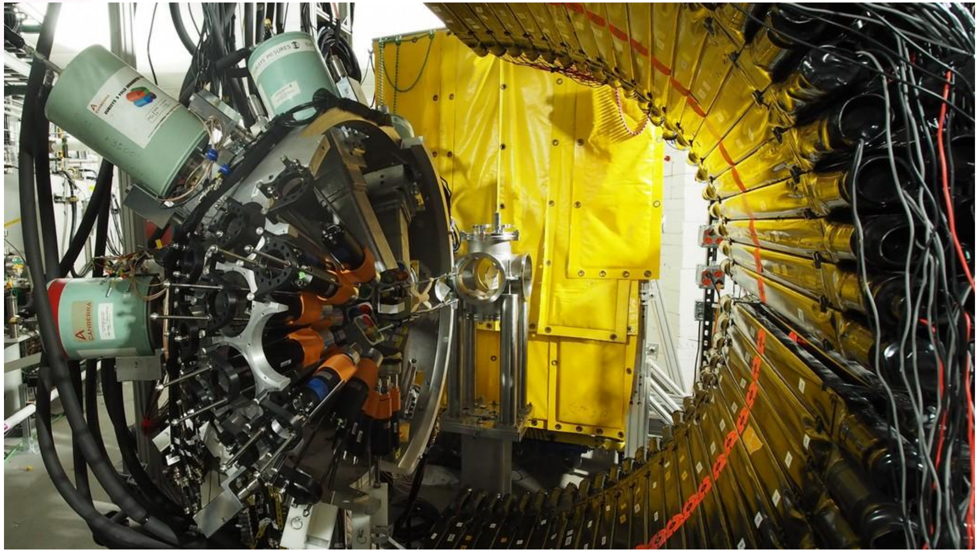


Figure 2.3. Schematic diagram of the Decay Station systems.

2016





2016: FRIB SAC endorses Decay Station

FRIB SCIENTIFIC ADVISORY COMMITTEE MEETS ON FRIB EXPERIMENTAL EQUIPMENT

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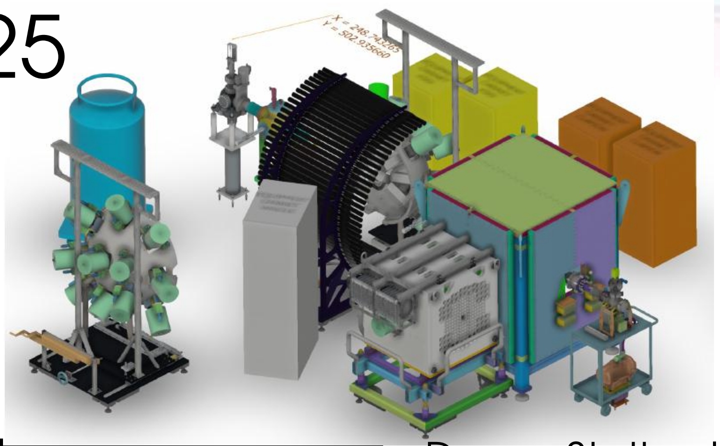
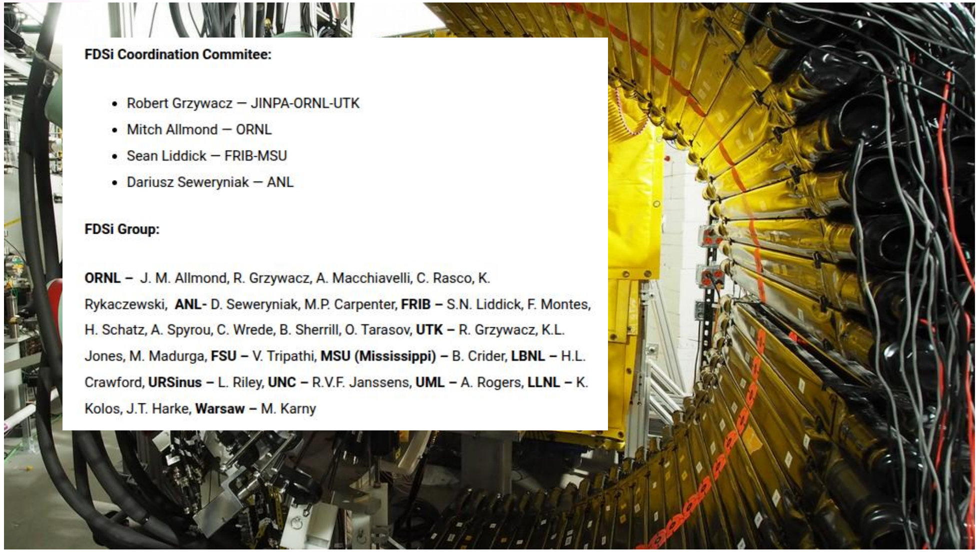
2025





FDSi Coordination Commitee:

- Robert Grzywacz — JINPA-ORNL-UTK
- Mitch Allmond — ORNL
- Sean Liddick — FRIB-MSU
- Dariusz Seweryniak — ANL

FDSi Group:

ORNL – J. M. Allmond, R. Grzywacz, A. Macchiavelli, C. Rasco, K. Rykaczewski, **ANL**- D. Seweryniak, M.P. Carpenter, **FRIB** – S.N. Liddick, F. Montes, H. Schatz, A. Spyrou, C. Wrede, B. Sherrill, O. Tarasov, **UTK** – R. Grzywacz, K.L. Jones, M. Madurga, **FSU** – V. Tripathi, **MSU (Mississippi)** – B. Crider, **LBNL** – H.L. Crawford, **URSinus** – L. Riley, **UNC** – R.V.F. Janssens, **UML** – A. Rogers, **LLNL** – K. Kolos, J.T. Harke, **Warsaw** – M. Karny

Decay Station Initiator

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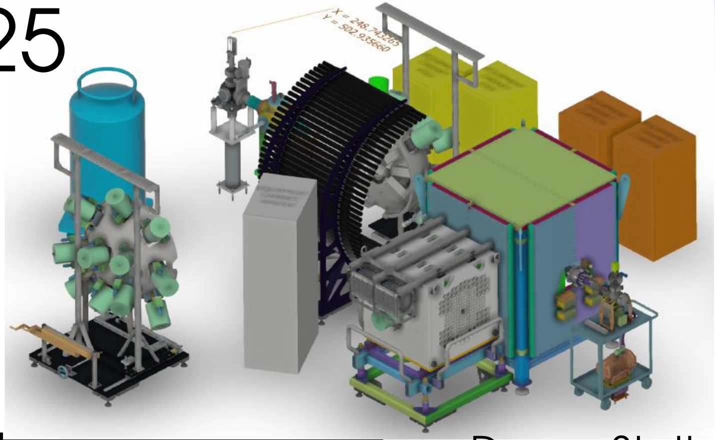
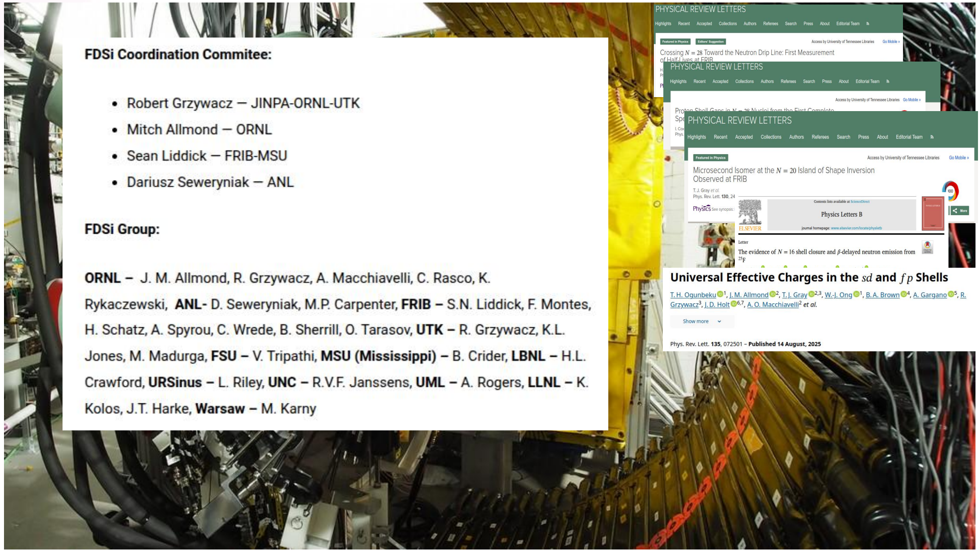
2025





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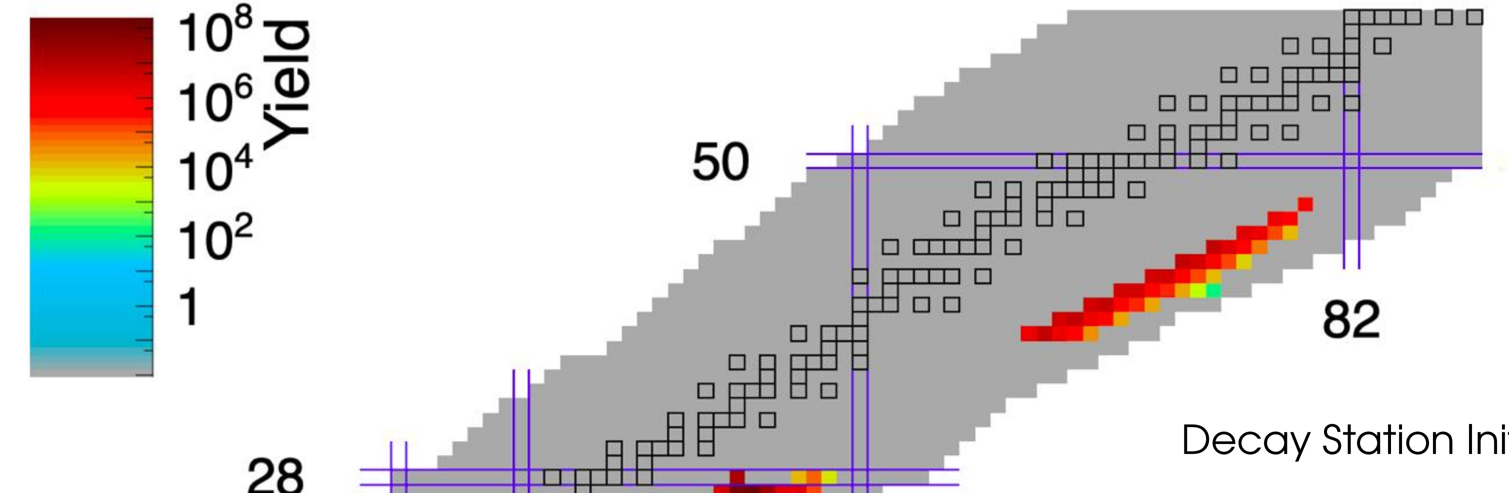
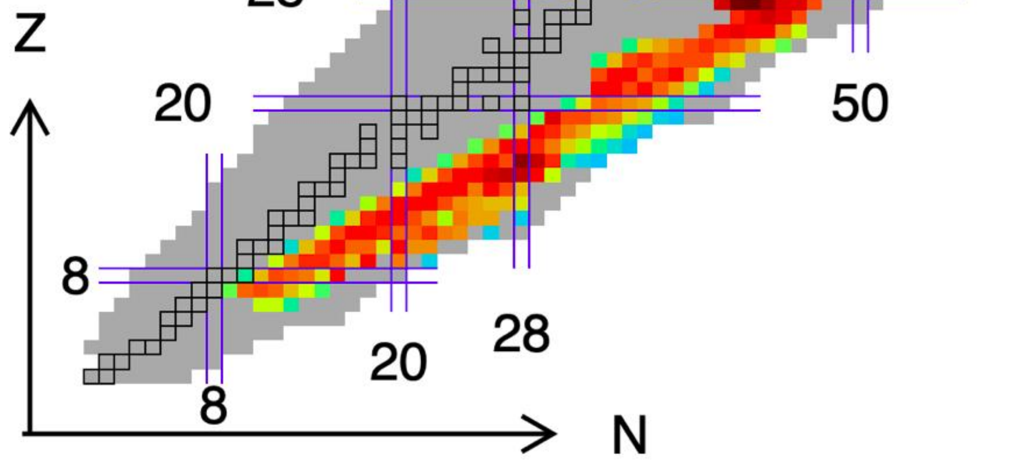
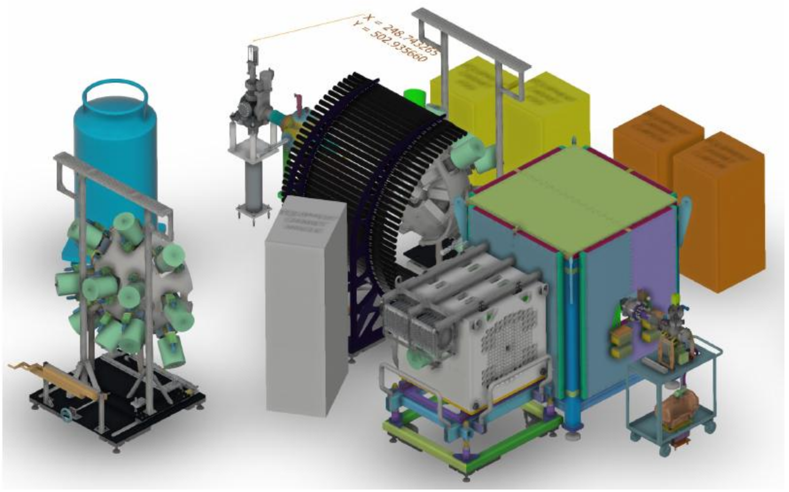
Decay Station Initiator

Range of n-rich nuclei investigated with FDSi Experiments 2022-2025





Decay Station Initiator



On the birth of an alpha particle

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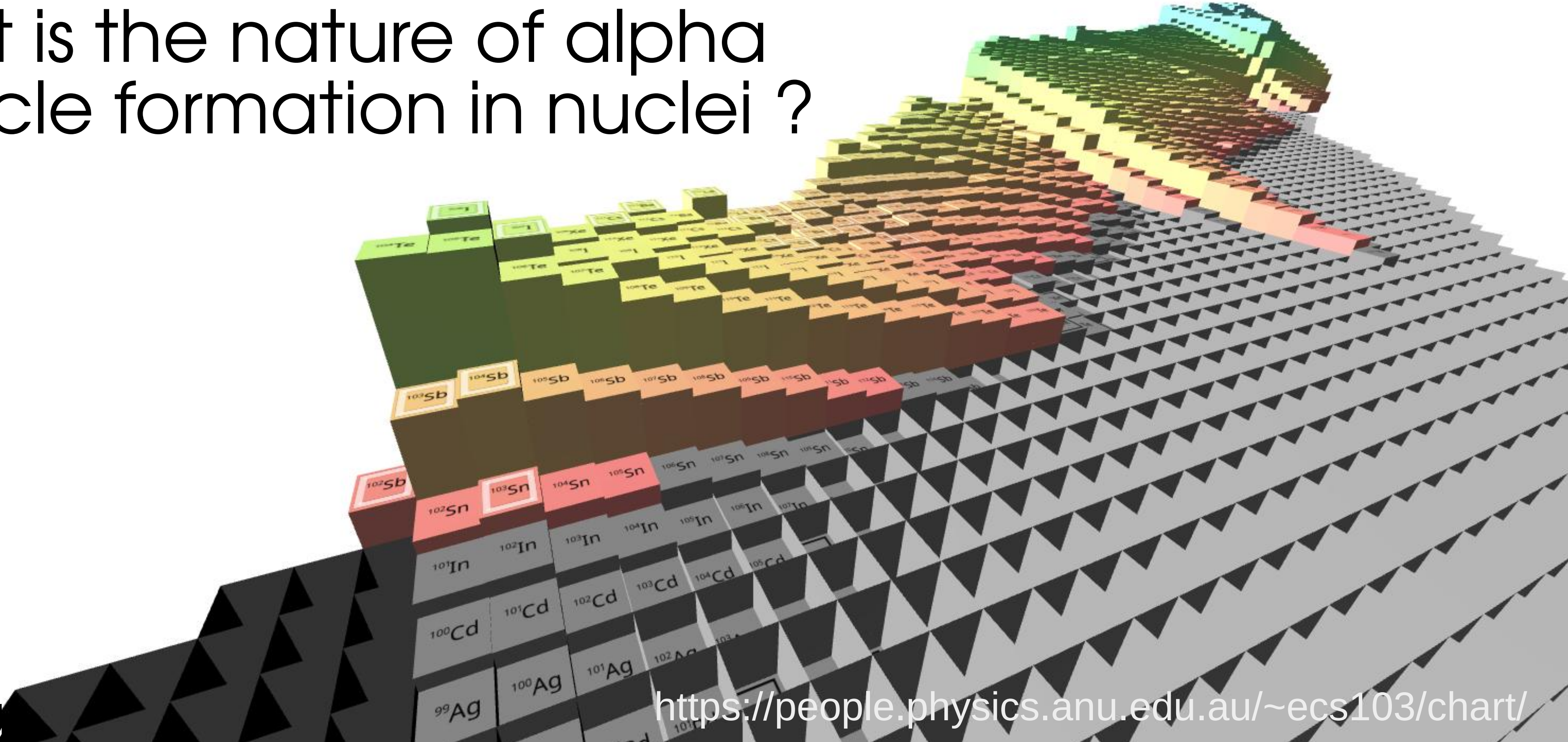
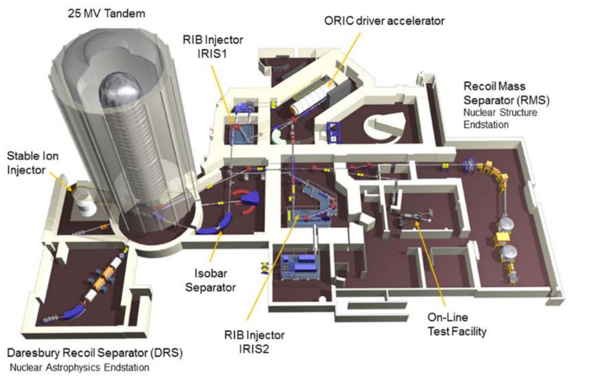


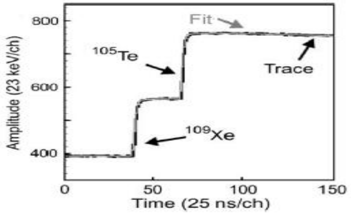
https://people.physics.anu.edu.au/~ecs103/chart/

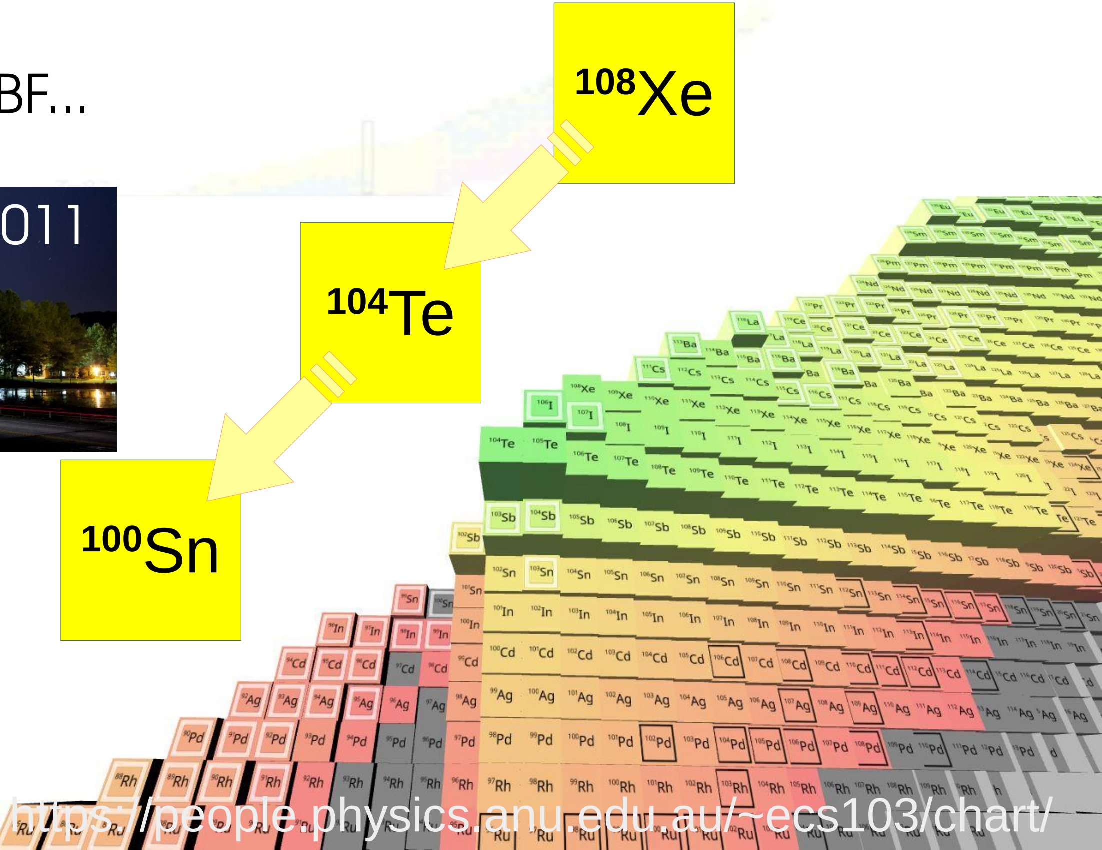
Superallowed Alpha Decay of ^{104}Te

^{104}Te expected to be the best candidate for the "superallowed" alpha decay

This story begins around 2003 at HRIBF...







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Superallowed Alpha Decay of ^{104}Te (@RIKEN)

19 The 19th Program Advisory Committee (PAC) Meeting for Nuclear-Physics Experiments at RI Beam Factory

The 19th Program Advisory Committee for Nuclear Physics experiments at RI Beam Factory will be held as follows.
The presentations at the meeting are open to the public.

Date: November 29-December 1, 2018
Place : RIBF Building, Conference Hall (2F)

2018

11:40	Closed Session (1)	
12:10	Business Lunch (50 min.)	
	BigRIPS/ZDS-2	
13:00	NP1812-RIBF168 Study of "superallowed" decay of lightest alpha emitters and proton emission near doubly-magic ^{100}Sn.	R. Grzywacz Univ. Tennessee
13:20	NP1812-RIBF169 Signatures of nuclear structure evolution in beta-delayed neutron emission towards ^{60}Ca region	R. Grzywacz Univ. Tennessee
13:40	NP1812-RIBF171 Nuclear shell structures and Gamow-Teller transitions in Sb, Te, I, Xe, and Cs far beyond ^{132}Sn with N = 88 to 94	B. Moon Korea Univ.
14:00	NP1812-RIBF152R1 Measurements of charge-changing and reaction cross sections of neutron-rich Ca isotopes	R. Kanungo St. Mary U / TRIUMF
14:20	Coffee Break (20 min.)	
	BigRIPS/ZD-3	

12 The 12th Program Advisory Committee (PAC) Meeting for Nuclear-Physics Experiments at RI Beam Factory

The 12th Program Advisory Committee for Nuclear Physics experiments at RI Beam Factory will be held as follows.
The presentations at the meeting are open to the public.

Date : June 28-29, 2013
Place : Conference Hall, RIBF Bldg (2F)

2013

RIBF100			
NP1306-RIBF101	Search for "superallowed" decay of lightest alpha emitter ^{104}Te; new testing ground for alpha clustering	R. Grzywacz	U. Tennessee / ORNL
NP1306-RIBF102	One-Step vs. Two-Step Fragment Yields for Very Neutron-Rich Isotopes	W. F. Henning	RNC / TU Muenchen / ANL
NP1306-RIBF104	Two-proton correlations in the decay of ^{54}Zn	M. Pfutzner/ Presentation by R. Grzywacz	U. of Warsaw/ U. Tennessee, ORNL

NP-PAC members

Name	Institute
Angela Bracco(Chair)	INFN
Dieter Ackermann	GANIL
Andrei Andreyev	University of York
Ikuko Hamamoto	Lund University
Robert V. F. Janssens	University of North Carolina at Chapel Hill
Augusto O. Macchiavelli	Lawrence Berkeley National Laboratory
David J. Morrissey	Michigan State University
Tomofumi Nagae	Kyoto University
Hitoshi Nakada	Chiba University
Alexandre Obertelli	Technische Universität Darmstadt
Kazuyuki Ogata	RCNP, Osaka University
Thomas Rauscher	University of Basel
Kimiko Sekiguchi	Tohoku University
Haik Simon	GSI
Piet Van Duppen	K. U. Leuven
Yuhu Zhang	Institute of Modern Physics, CAS

Superallowed Alpha Decay of ^{104}Te (@RIKEN)

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Date: November 29-December 1, 2018

Place : RIBF Building, Conference Hall (2F)

2018

2020

COVID !!!

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12:10	Business Lunch (50 min.)	
	BigRIPS/ZDS-2	
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Superallowed Alpha Decay of ^{104}Te (@RIKEN) "The third time's a charm"

The 23rd Program Advisory Committee (PAC) Meeting for Nuclear-Physics Experiments at RI Beam Factory

Date: December 5-7, 2022

RIBF Building Conference Hall (2F) & online via Zoom

December 5 (Mon.)

RIBF Building, Conference Hall (2F) & Zoom

14:10		*Coffee Break (20 min.)*		
	BigRIPS/ZD-4			
14:30 (20)		**NP2212-RIBF222 (ON-SITE)**	**J. PARK**	**IBS**
14:50 (20)		**NP2212-RIBF168R1 (ON-SITE)**	**R. GRZYWACZ**	**Univ. of Tennessee / ORNL**
15:10 (20)		**NP2212-RIBF214 (ON-SITE)**	**K. ITAHASHI**	**RIKEN**
15:30 (20)		**NP2212-RIBF205R1**	**S. KIMURA**	**RIKEN**
	SAMURAI-1			
15:50 (20)		**NP2212-SAMURAI32R3**	**M. SASANO**	**RIKEN**
16:10		*Coffee Break (20 min.)*		

RIKEN NISHINA CENTER

- Grade S (days including BigRIPS tuning time)
  - RIBF168R1 6 days
  - SAMURAI74 11.5 days
- Grade A
  - AVF65R1 11 days
  - RRC77 9 days
  - RRC78 3 days
  - RRC79 6 days
  - RIBF214 4 days
  - RIBF138R2 9 days
  - RIBF216 4 days
  - RIBF217 4 days
  - RIBF229 3.5 days
  - RIBF205R1 2 days
  - RIBF230 7 days
  - RIBF232 3 days
  - SHARAQ21R1 2.5 days
  - RIRING03R1 9 days
  - SAMURAI32R3 6 days
  - SAMURAI66R1 3 days

NP-PAC members

Name	Institute
M. J. G. Borge	Consejo Superior de Investigaciones Científicas
S. Grevy	Centre d'Etudes Nucléaires de Bordeaux Gradignan
M. Dasgupta	The Australian National University
J. Dilling	Ork Ridge National Laboratory
M. Gorska	GSI Darmstadt
T. Kawabata	Osaka University
M. Matsuo	Niigata University
R. Zegers	Michigan State University
N. Aoi	RCNP, Osaka University
R. Charity	Washington University in St. Louis
G. Martínez-Pinedo	Technische Universität Darmstadt / GSI Helmholtzzentrum für Schwerionenforschung
I. Moore	University of Jyväskylä
T. Saito	RIKEN
P.J. Woods	University of Edinburgh
A. Vitturi	Universita' di Padova
X. Zhou	Chinese Academy of Sciences

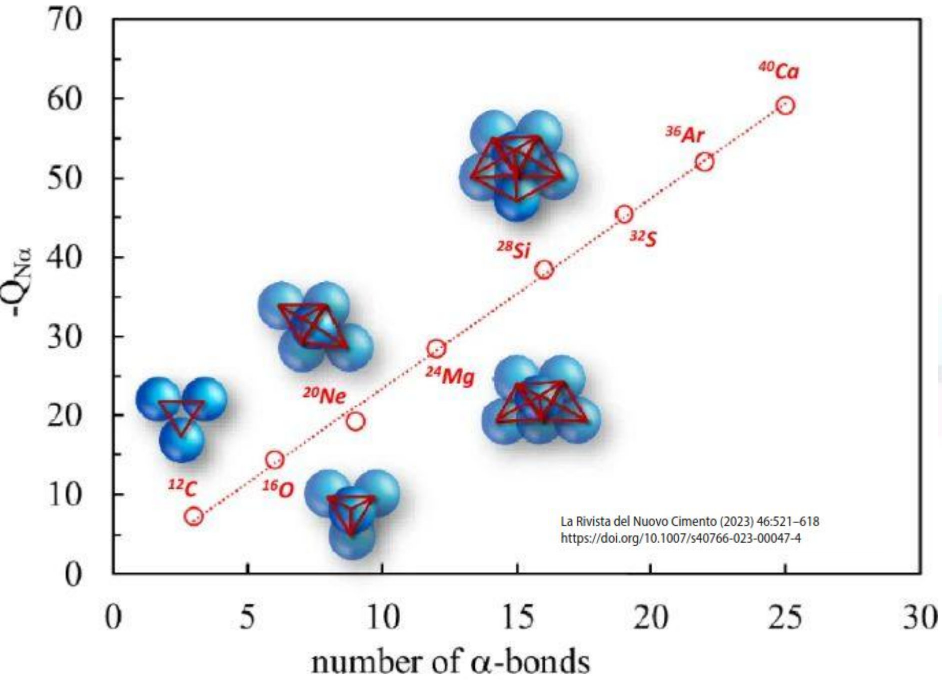
NUCLEAR PHYSICS

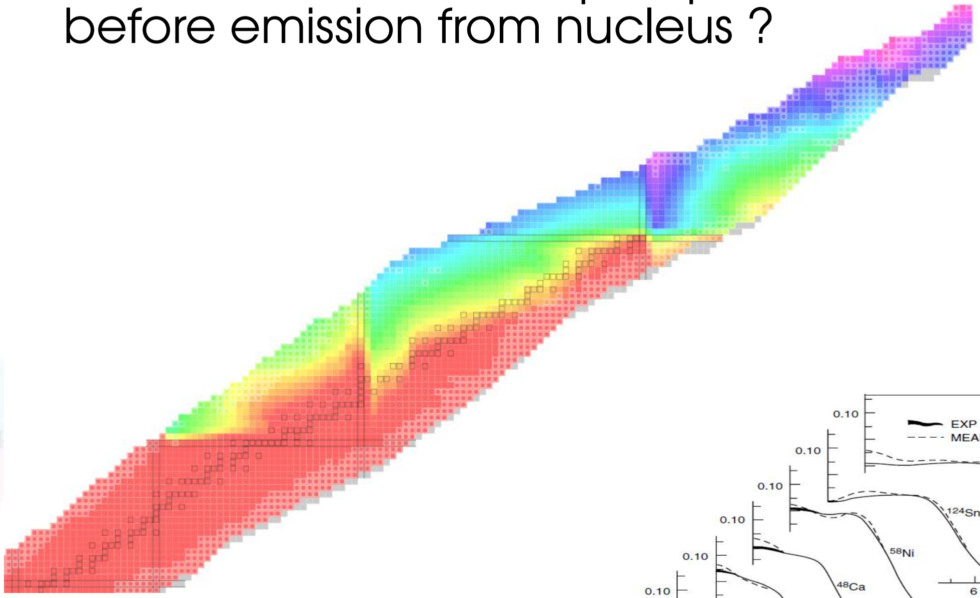
Formation of α clusters in dilute neutron-rich matter

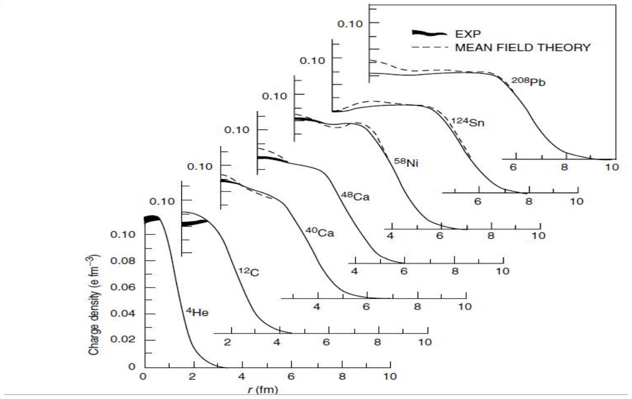
Junki Tanaka[1,2,3]*, Zaihong Yang[3,4]*, Stefan Typel[1,2], Satoshi Adachi[4], Shiwei Bai[5], Patrik van Beek[1],

Alpha decay and pre-formation problem

How and where the alpha particle form before emission from nucleus ?







B. Frois, Proc. Int. Conf. Nucl. Phys., Florence 1983

Alpha particle pre-formation

What is the measure of preformation ?
Reduced width (Rasmussen)
(P- barrier penetrability with spherical potential)

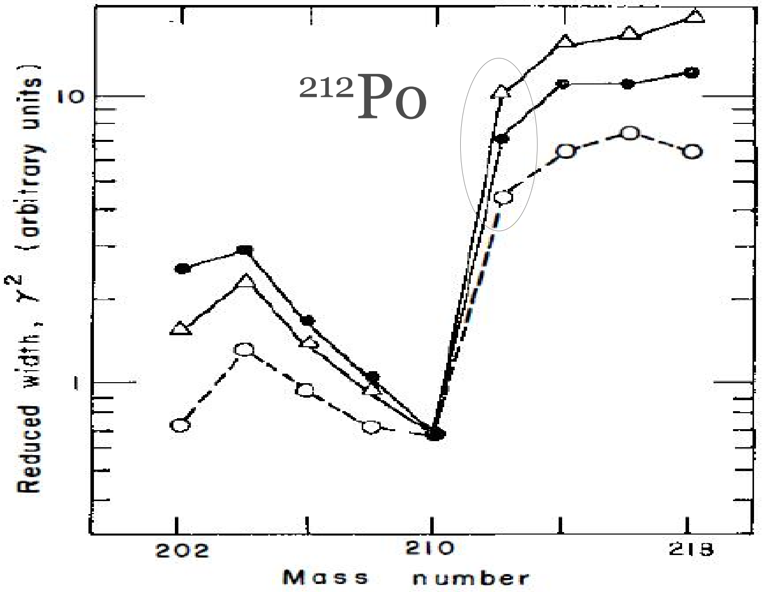
$$1/\tau=\lambda_\alpha=P\delta^2/h$$

Reference case:
alpha+doubly magic ^{208}Pb: ^{212}Po

$$W_\alpha=\delta^2/\delta^2(^{212}\mathrm{Po})$$

Cluster models:
Nucleus treated as a system core+alpha(s)
Shell-model:
Alpha particle emergent from the nuclear wave-function

$$\lambda=A_\alpha^2 fP$$
$$A_\alpha^2=\left|\langle\psi_i(A)|\psi_f(A-4)\phi(4)\rangle\right|^2$$



H. Mang PRC 119(1960) 1069

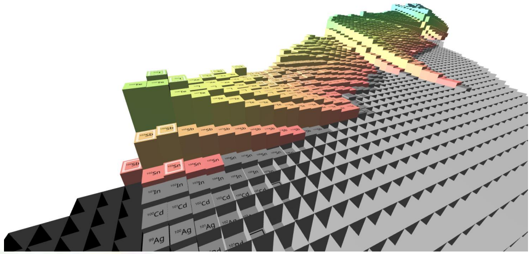
65 years

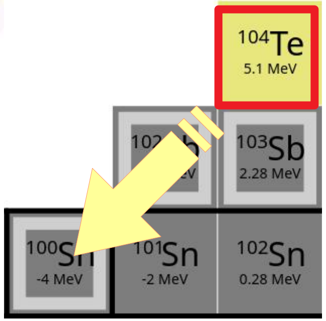
Alpha clusters in spherical heavy nuclei ?
"superallowed" alpha decay

$^{104}Te = {}^{100}Sn + \alpha$

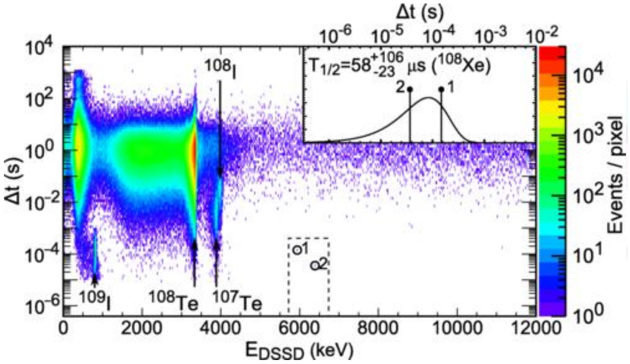
Proposed by Macfarlane in 1965

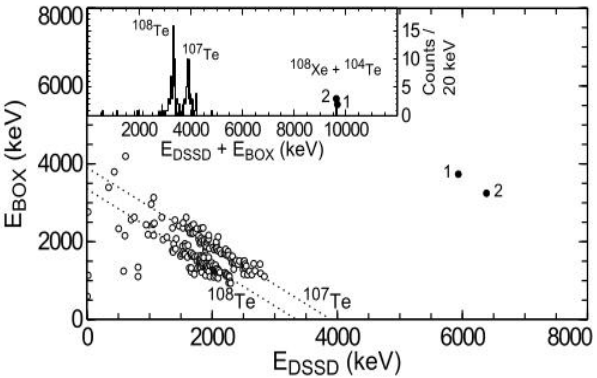
- Enhanced alpha pre-formation due to proximity of N=Z
  protons and neutrons occupies the same orbits !
- Small degree of alpha clusterisation postulated at ^{208}Pb region
- Experiments on $^{105,106}Te$ observed increased decay probability
- Conflicting model predictions for ^{104}Te alpha decay !





Strong suggestion for superallowed alpha decay based on 2 events in fusion reaction. Two alpha particles not resolved.





^{108}Xe (Ea=4.4(2) MeV, $T_{1/2} = 58^{+106}_{-23}$
^{104}Te (Ea=4.9(2) MeV, $T_{1/2}$ <18 ns)

Auranen et al. Phys. Rev. Lett. 121, 182501 (2018)

a - preformation, surge in theory interest
The decays of heavy and superheavy nuclei

Significant efforts experimental and theoretical to address directly the ^{104}Te decay.

Predictions: W_a~4.

2 observed events provide upper limit on lifetime $T_{1/2}$ < 18 ns and energy estimate E_a=4.9(2) MeV.

The W_a~13.1 is unexpectedly large.

Auranen et al. Phys. Rev. Lett. 121, 182501 (2018)

C. Xu and Z. Ren, Phys. Rev. C 74, 037302 (2006).
F. R. Xu and J. C. Pei, Phys. Rev. Lett. B 642, 322 (2006).
P. Mohr, Eur. Phys. J. A 31, 23 (2007).
C. Qi et al., Phys. Rev. C 81, 064319 (2010).
J. P. Maharana, A. Bhagwat, and Y. K. Gambhir, Phys. Rev. C 91, 047301 (2015)
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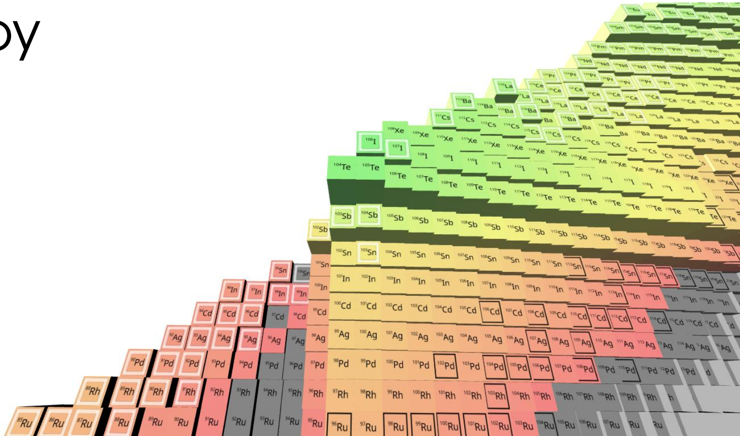
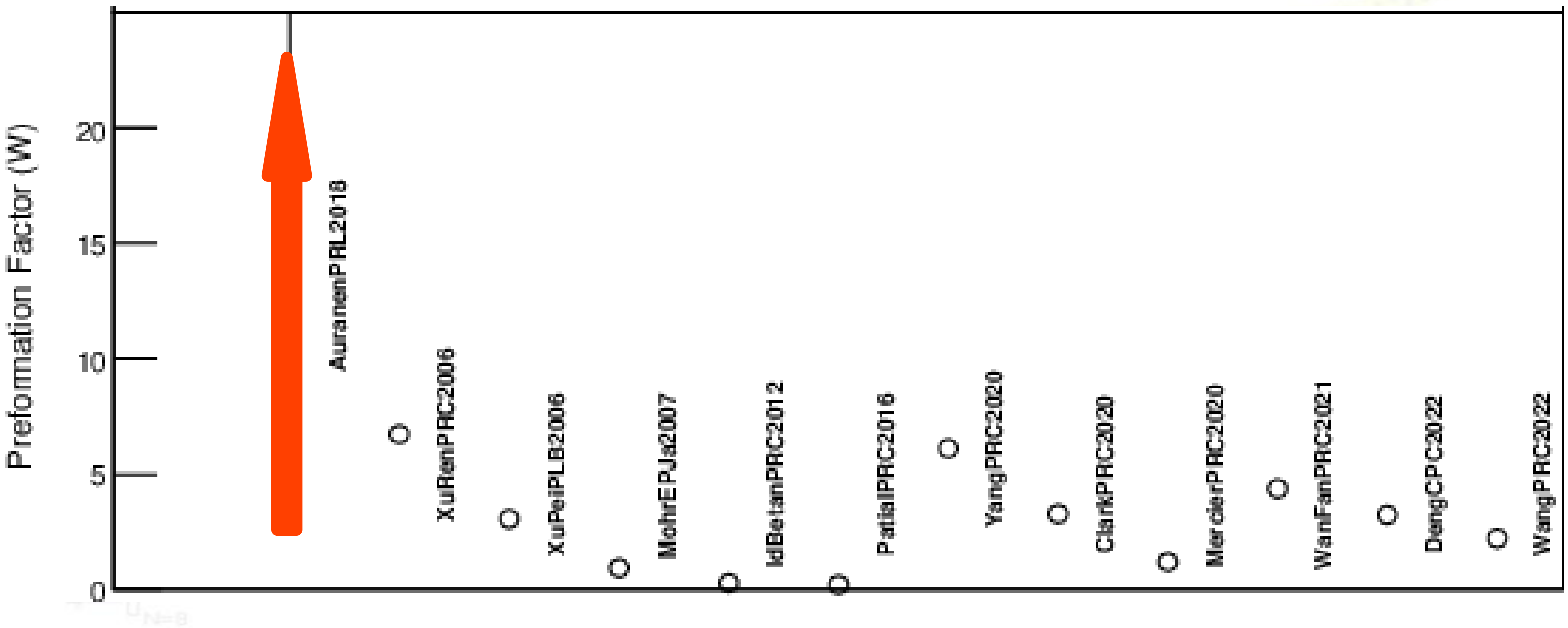
C. Qi , R. Wyss , Phys. Scr. 91, 013009 (2015).
M Patial, R J. Liotta, R Wyss, Phys. Rev. C 93, 054326 (2016).
C. Xu et al., Phys. Rev. C 93, 011306(R) (2016).
V. V. Baran, D. S. Delion, Phys. Rev. 94, 034319 (2016).
C. Xu el al., Phys. Rev. C 95, 061306(R) (2017).
C. Qi , R. Liotta, R. Wyss, Prog. Part. Nucl. Phys. 105, 214 (2019).
T. Togashi et al., Phys. Rev. Lett. 121, 062501 (2018)
D. Bai, Z. Ren, and G. Röpke, Phys. Rev. C 99, 034305 (2019).
R. M. Clark et al., Phys. Rev. C 101, 034313 (2020).
F. Mercier et al., Phys. Rev. C 102, 011301(R) (2020).
C. Qi, R. J. Liotta, R. Wyss, Phys. Lett. B 818, 136373 (2021).
S. Yang et al., Phys. Rev. C 101, 024316 (2020)
J. Tanaka et al., Science, 371, 6526, (2021).
N. Wan and J. Fan, Phys. Rev. C 104, 064320 (2021).
S. Yang, C. Xu, and G. Röpke Phys. Rev. C 104, 034302 (2021).
J.G. Deng et al., 2022 Chin. Phys. C 46, 061001 (2022).

Further studies with fusion-evaporation are limited by the very low cross section and thin targets.



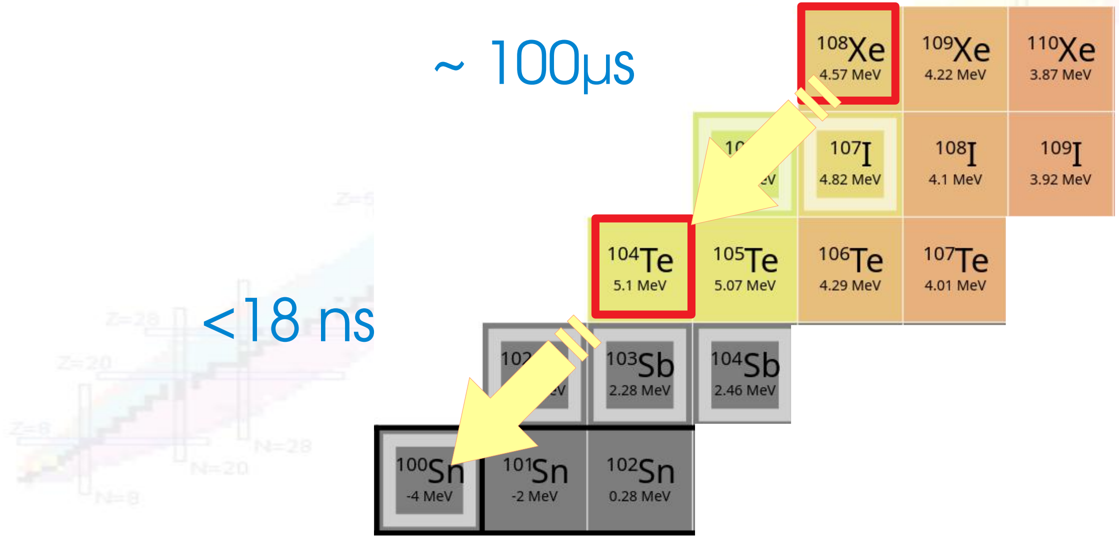
Experiment and theory



Directly produced ^{104}Te cannot be electromagnetically separated

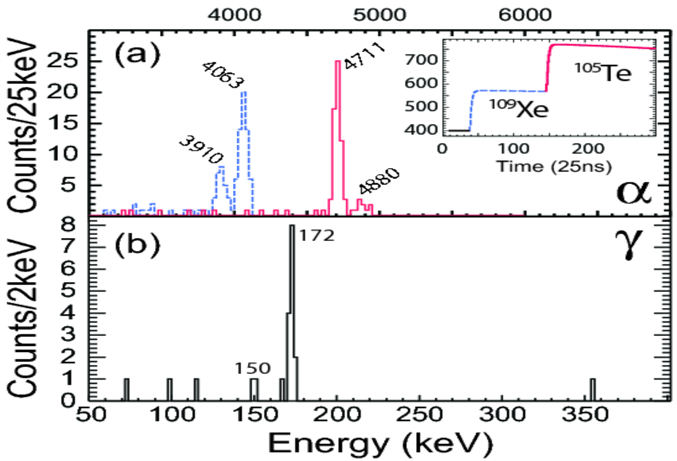
Use longer lived ^{108}Xe to populate short lived ^{104}Te

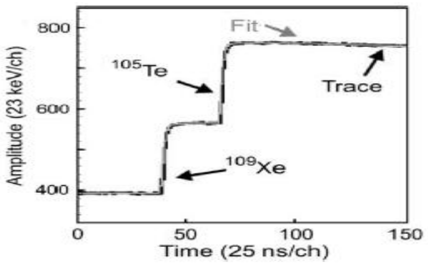
$$^{108}\mathrm{Xe} \rightarrow {}^{104}\mathrm{Te} \rightarrow {}^{100}\mathrm{Sn}$$

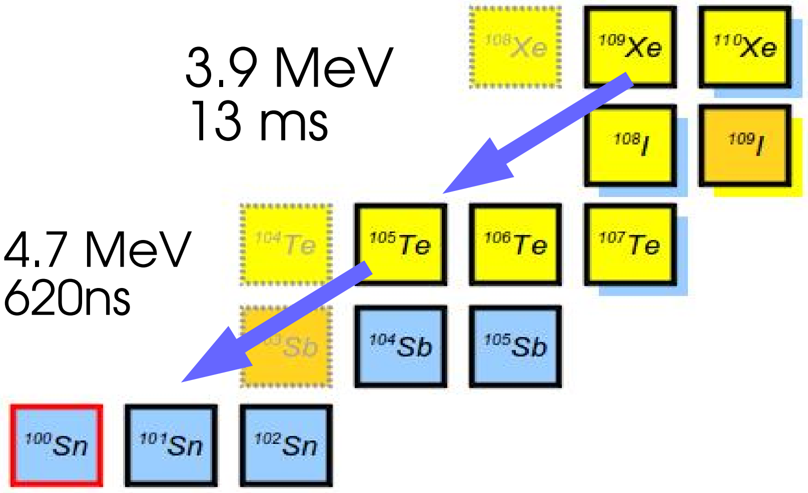


Experimental method to measure ^{104}Te

Implemented for the first time at ORNL in ^{58}Ni+^{54}Fe reaction (around 2005) led to discovery of ^{109}Xe alpha-decay chain.
Implant in position sensitive detector.
Record fast pileup pulses using digital signal processing methods.





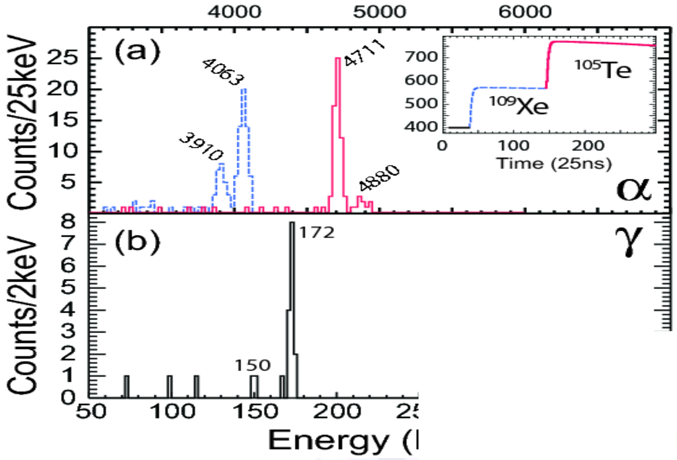


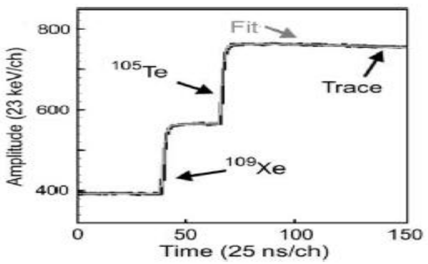
Silicon detector response is too slow to measure $T_{1/2}$~ 10 ns.
New technology needed to overcome DSSD limitations.

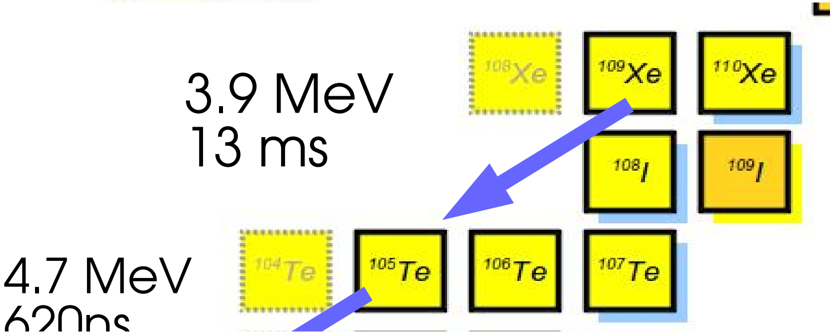
(Lid06) S.N. Liddick et al, Phys. Rev. Lett. **97**,082501 (2006)
(Grz07) R. Grzywacz et al., NIM B **261**, 1103 (2007).
(Dar10) I. Darby et al., Phys. Rev. Lett. **105**, 162502 (2010).
(Lid12) S.N. Liddick, I.G. Darby and R.K. Grzywacz NIM A **669**, 70 (2012)

Experimental method to measure ^{104}Te

Implemented for the first time at ORNL in ^{58}Ni+^{54}Fe reaction (around 2005)
led to discovery of ^{109}Xe alpha-decay chain.
Implant in position sensitive detector.
Record fast pileup pulses using digital signal processing methods.







Silicon detector respons
New technology neede

PHYSICAL REVIEW C **93**, 021601(R) (2016)

Structure of ^{107}Sn studied through single-neutron knockout reactions

G. Cerizza,[1,*] A. Ayres,[1] K. L. Jones,[1] R. Grzywacz,[1] A. Bey,[1] C. Bingham,[1] L. Cartegni,[1] D. Miller,[1,†] S. Padgett,[1,‡] T. Baugher,[2,§] D. Bazin,[2] J. S. Berryman,[2] A. Gade,[2] S. McDaniel,[2] A. Ratkiewicz,[2,‡] A. Shore,[2] S. R. Stroberg,[2,‖] D. Weisshaar,[2] K. Wimmer,[2,¶] R. Winkler,[2] S. D. Pain,[3] K. Y. Chae,[3,**] J. A. Cizewski,[4] M. E. Howard,[4] and J. A. Tostevin[5]

Towards neutron knockout from ^{102}Sn

Fast inorganic scintillator enables measurements of fast decay chains

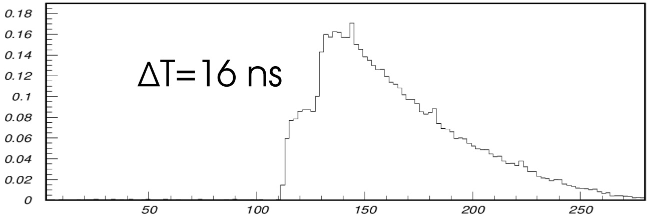
Xiao et al. PHYSICAL REVIEW C 100, 034315 (2019)

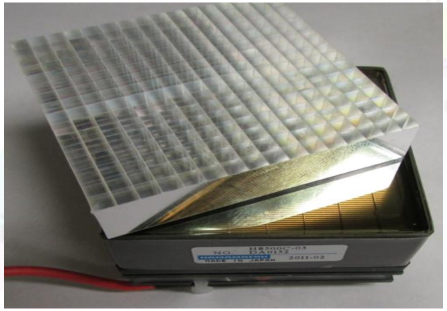
Inorganic scintillators
(YSO, YAP, LYSO, $CeBr_3$) :
- fast rise time (~1-2ns)
- short-decay time (30-60ns)
- bright (resolution ~8-10 %)

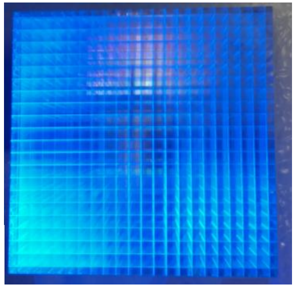
Fast digitization (500 MHz, 2ns) enables to resolve pile-up pulses in nanosecond range.

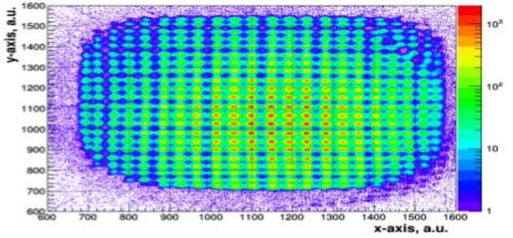
Fragmentation !
Light quenching enables to measure energetic heavy ion (10 GeV) and decay induced signals (1-5 MeV).

Yokoyama et al. NIMA 93 (2019) 93-97
M. Singh NIM A. 1073 (2025), 170239
B. Kreider et al. https://arxiv.org/pdf/2508.15513
Y. Xiao et al. Phys. Rev. C 100, 034315, 2019

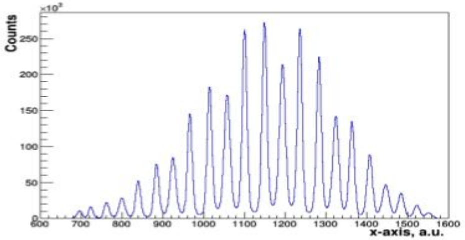


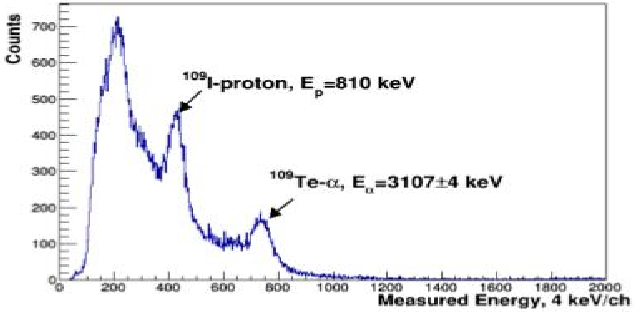






(a)





Physics Procedia
Volume 66, 2015, Pages 445-450

Development of a Segmented Scintillator for Decay Studies ☆

Mohammad Alshudifat, R. Grzywacz, S.V. Paulauskas

Fast inorganic scintillator enables measurements of fast decay chains

Xiao et al. PHYSICAL REVIEW C 100, 034315 (2019)

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(YSO, YAP, LYSO, $CeBr_3$) :
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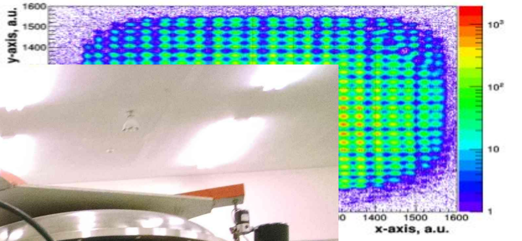
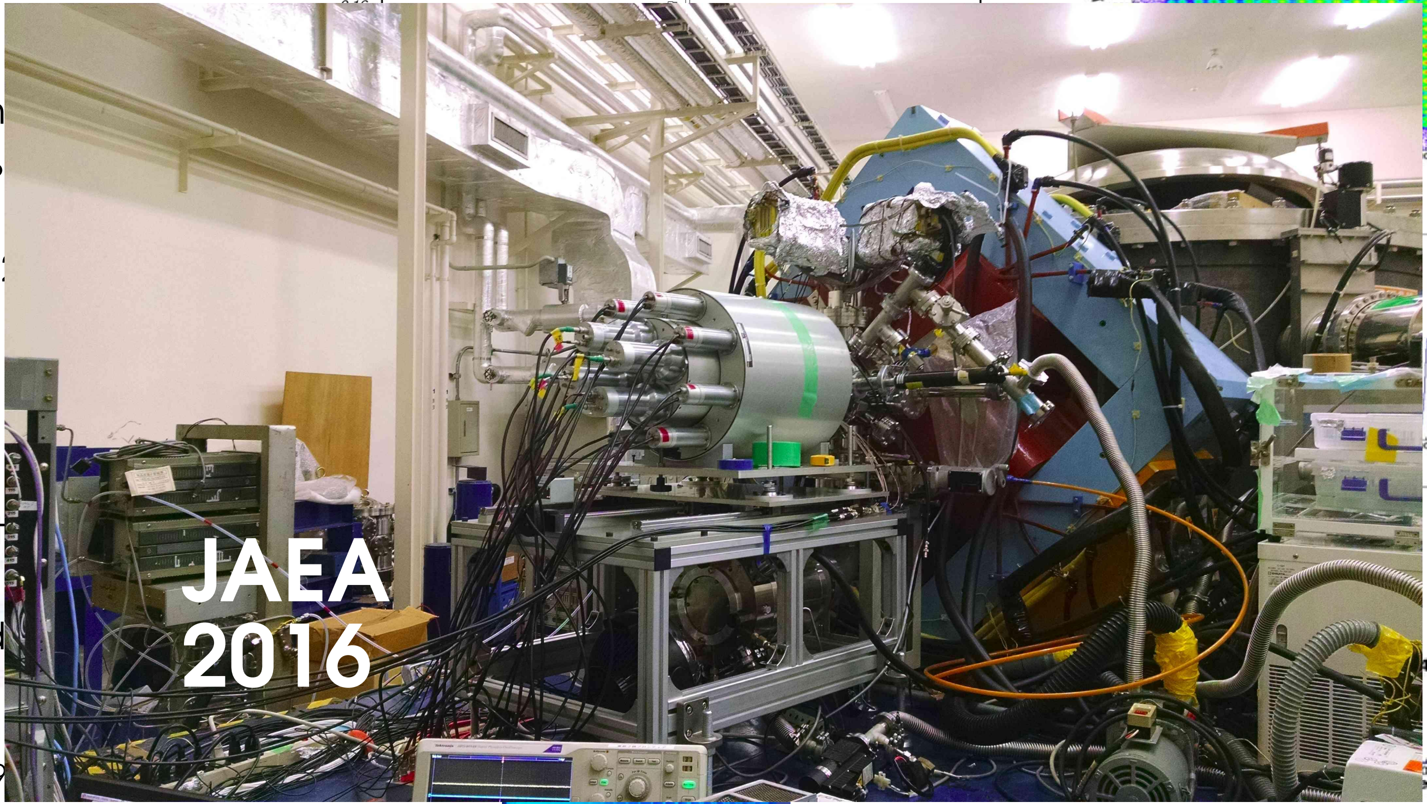
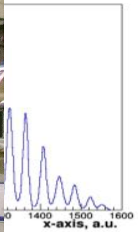
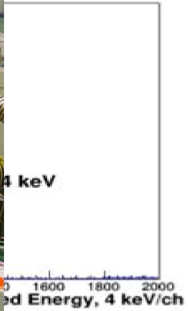








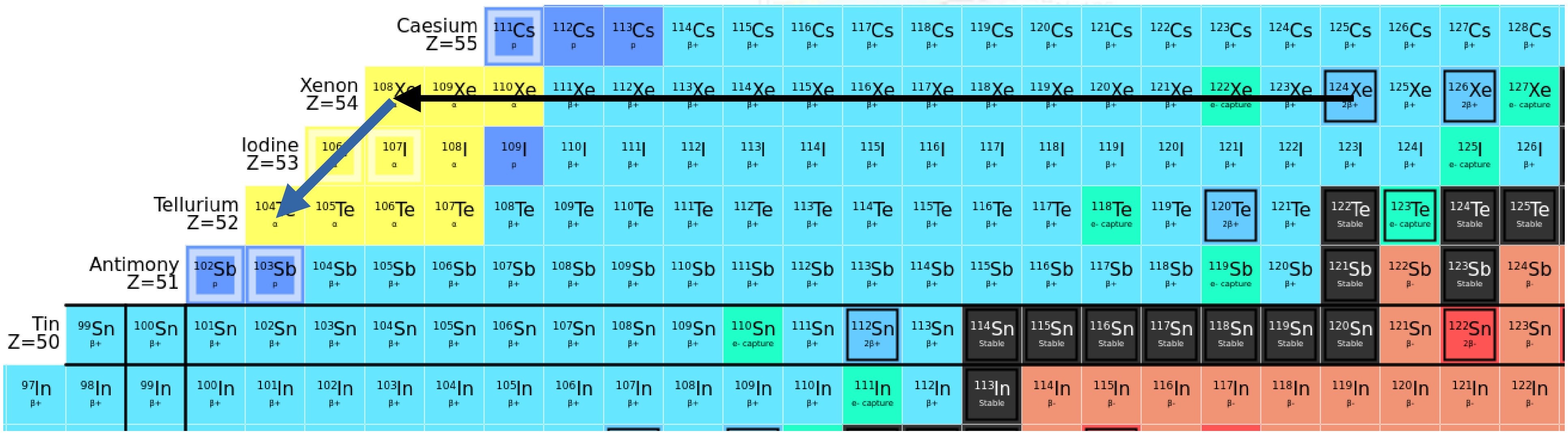
Yokoyama et al. NIMA 93 (2019) 93-9
M. Singh NIM A. 1073 (2025), 170239
B. Kreider et al. https://arxiv.org/pdf/2508.15513
Y. Xiao et al. Phys. Rev. C 100, 034315, 2019

^{108}Xe from ^{124}Xe fragmentation

Experiment: 140 pnA (6kW), $^{124}Xe^{52+}$ beam 345 MeV/u on 6 mm ^{9}Be target

- "Nominal" (Epax 3.01) production cross section of ^{108}Xe ~ 60 fb resulting in 6 ions/hour of ^{108}Xe.
- Empirical reduction factor of 20 observed for ^{105}Te would result in 7 particles/24 hours.
- A reduction factor of 100 was observed for ^{67}Kr fragments from ^{78}Kr fragmentation (removal of 11 neutrons).

^{108}Xe=^{124}Xe - 16 neutrons



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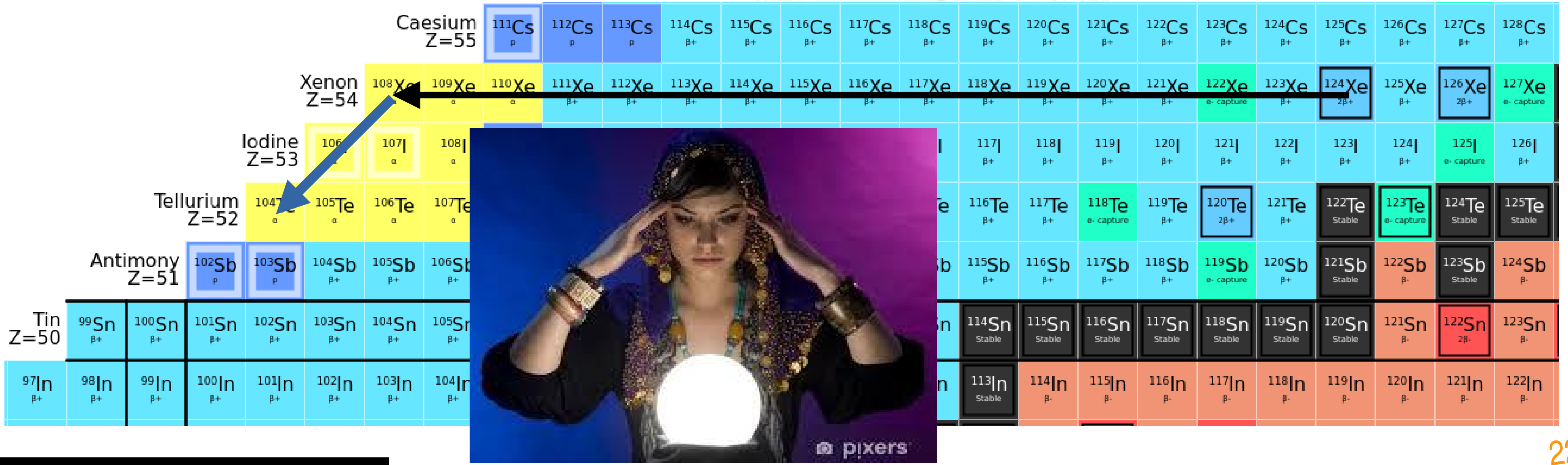
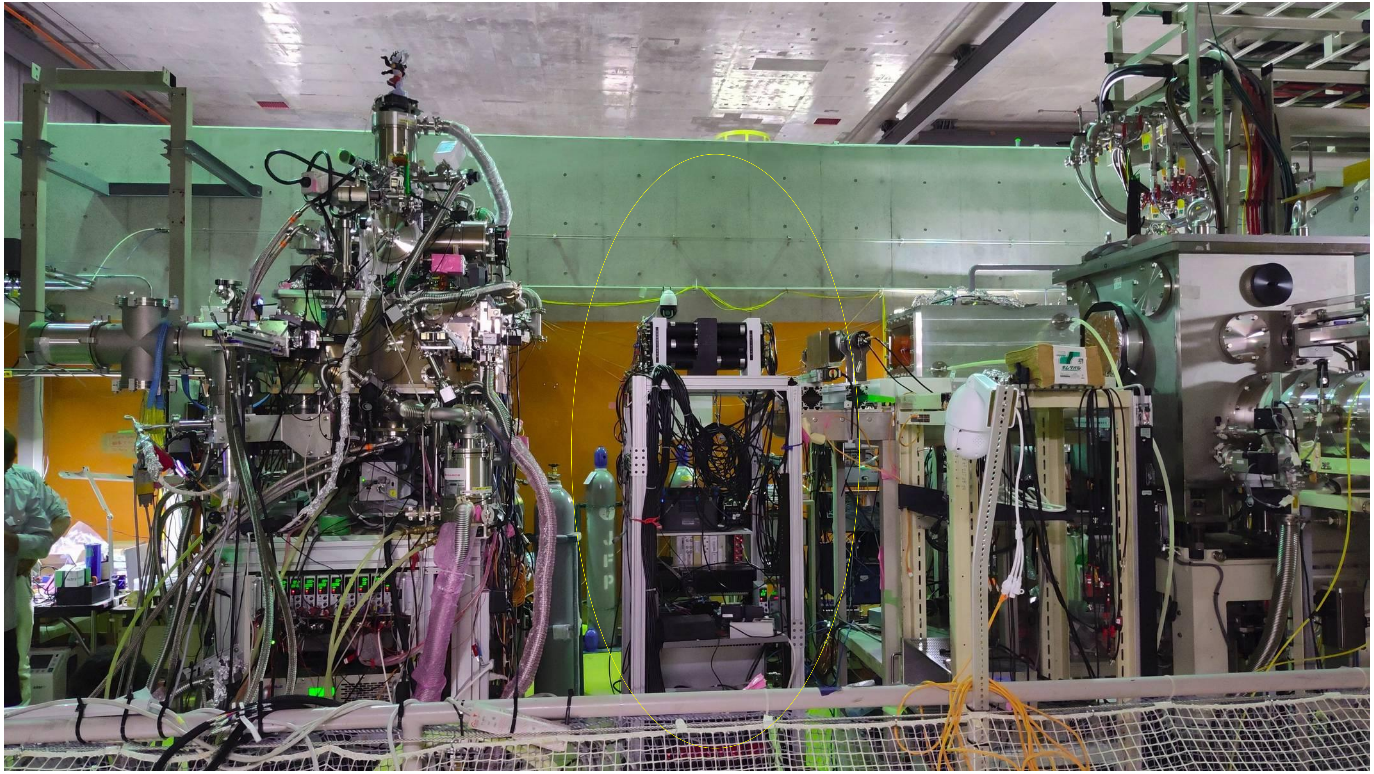
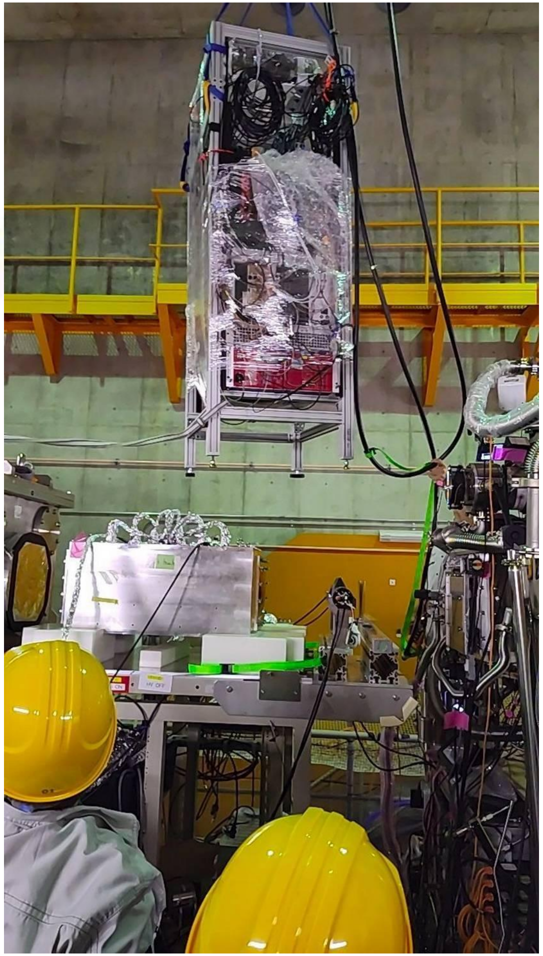
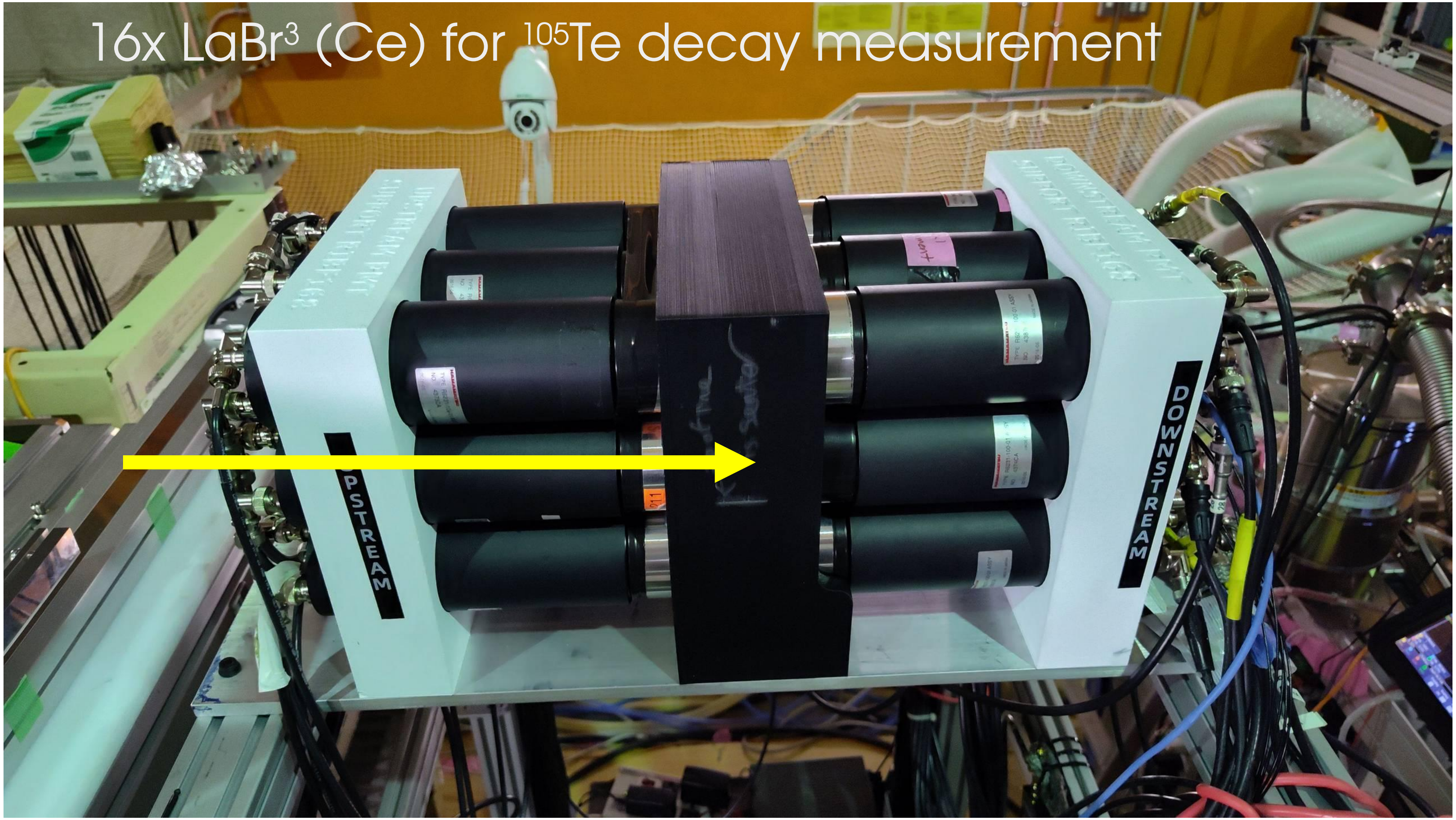


Experimental setup (RIBF June 2024)

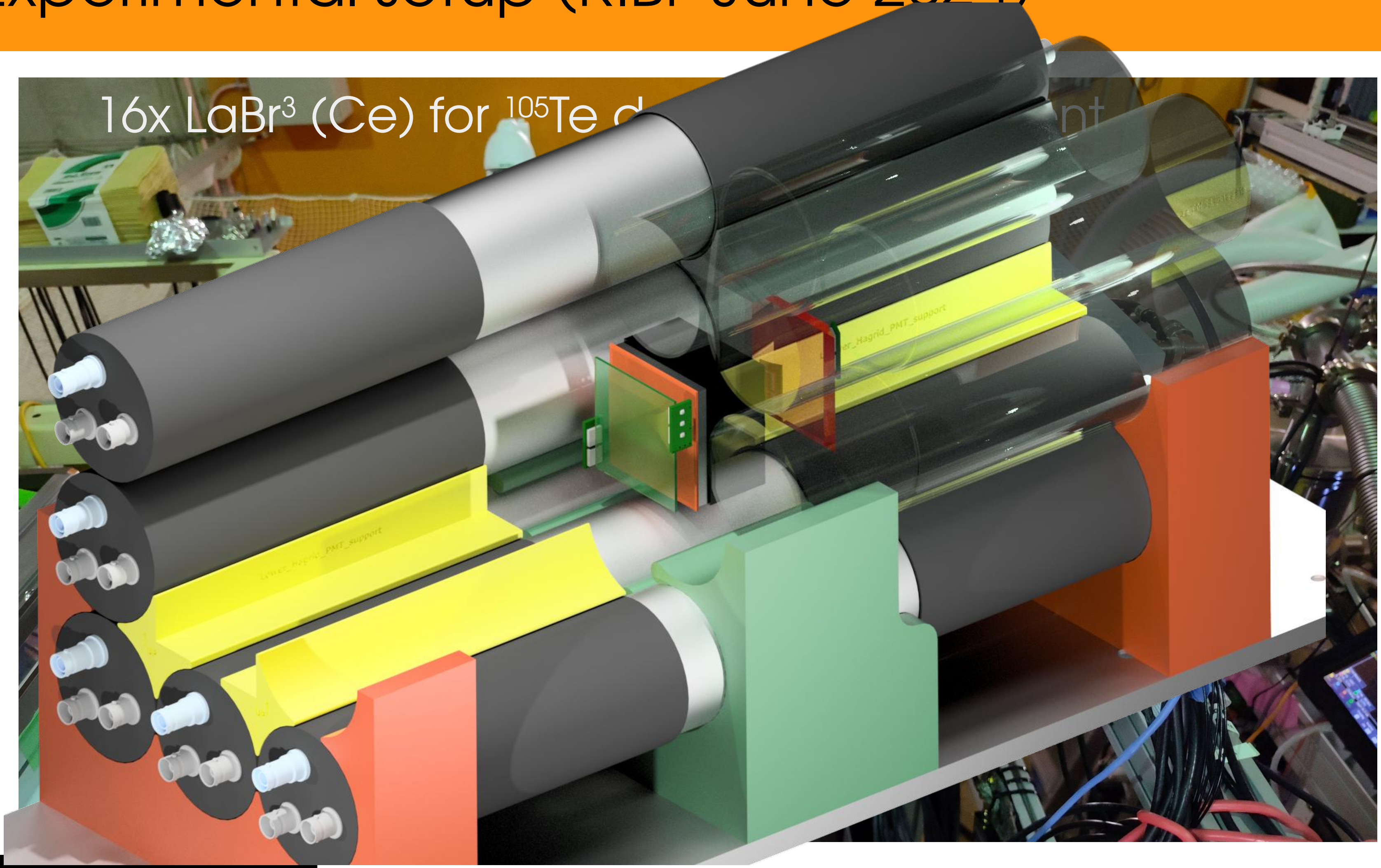




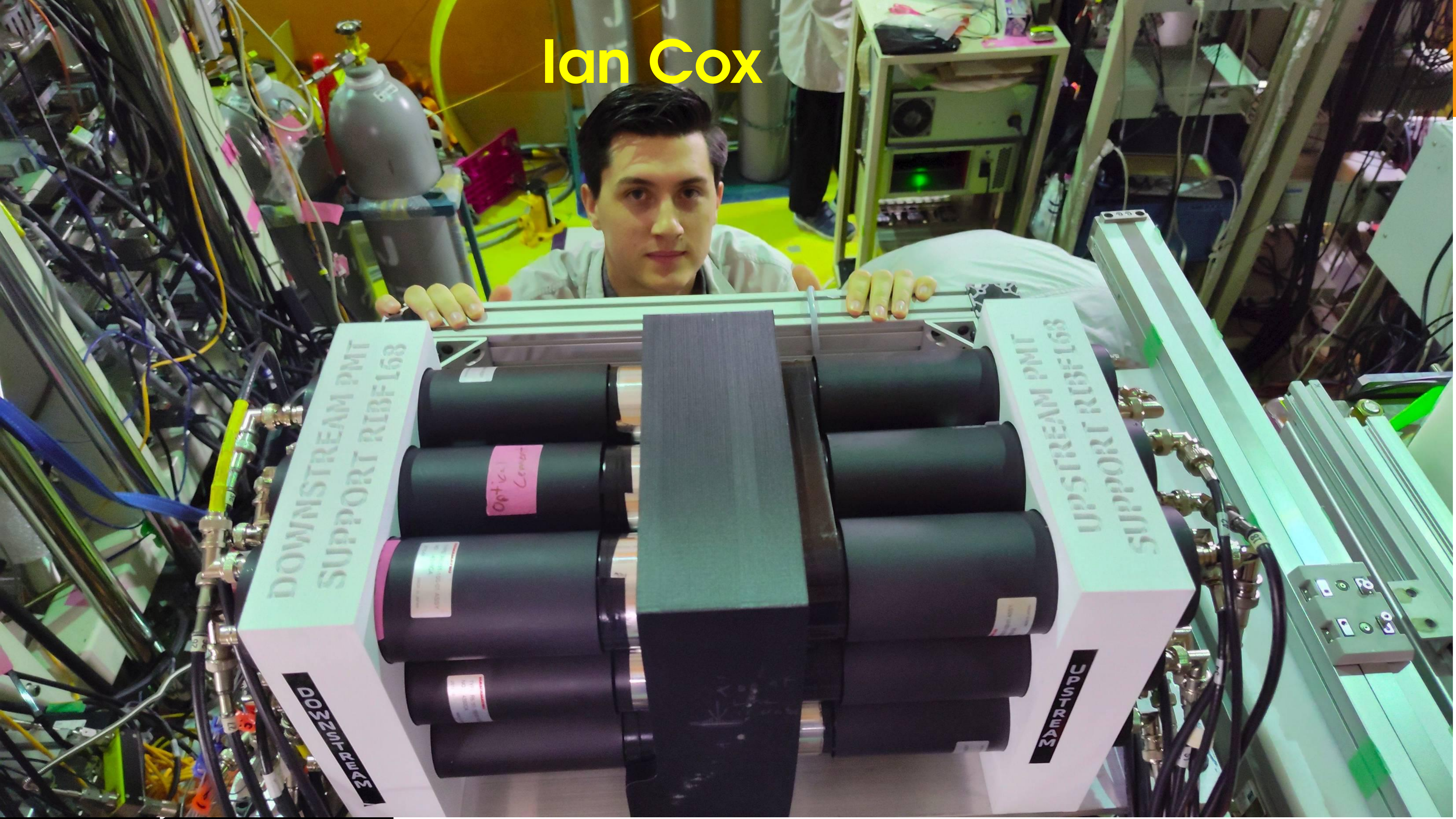
Experimental setup (RIBF June 2024)



Experimental setup (RIBF June 2024)



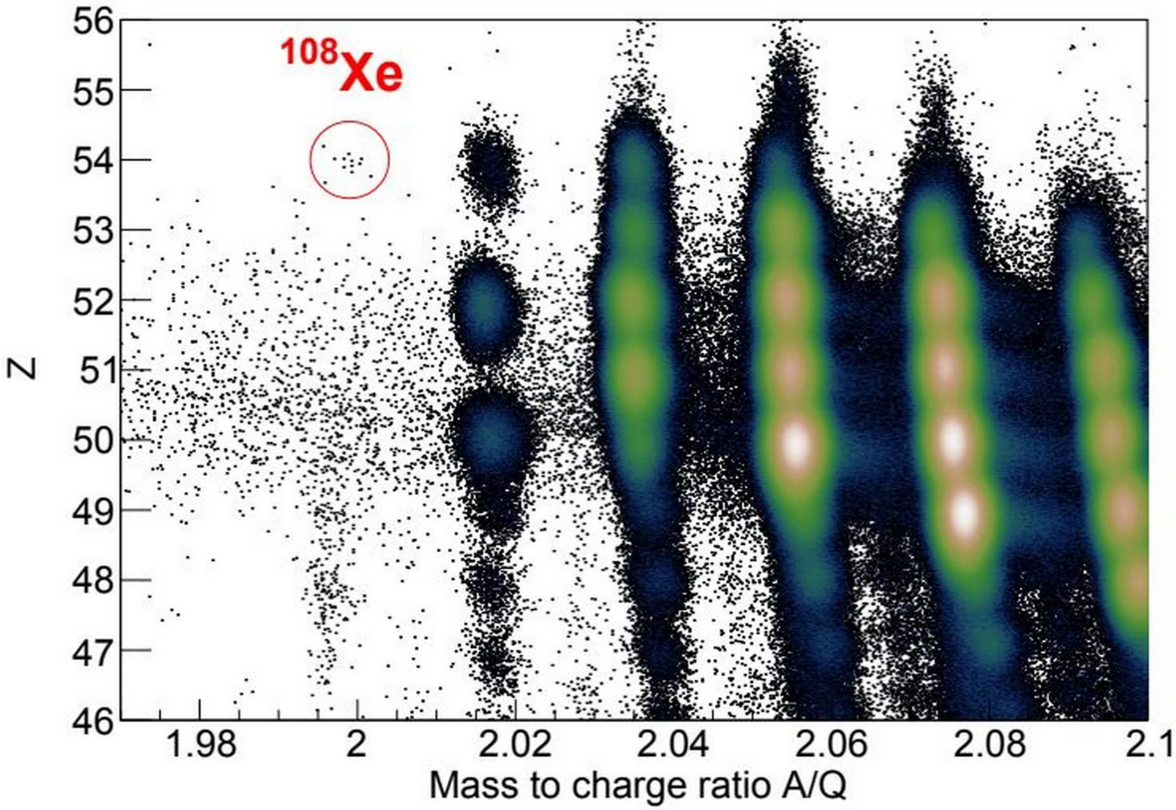
Ian Cox

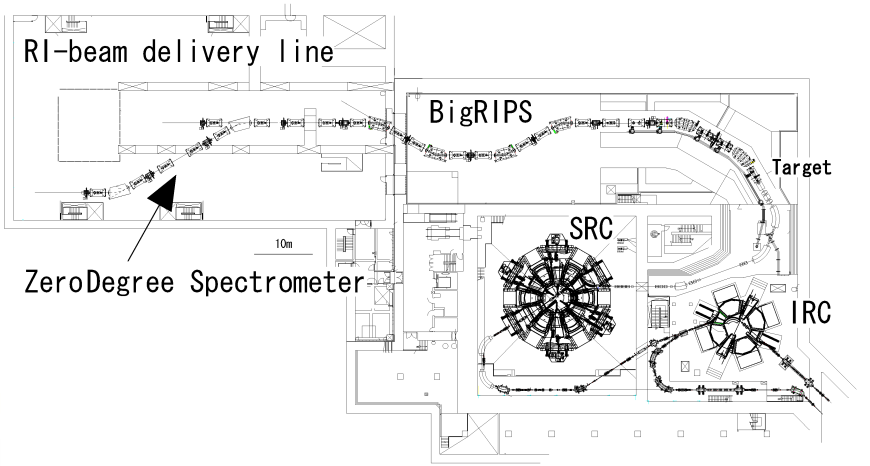

DOWNSTREAM PMT
SUPPORT RIBF168
UPSTREAM PMT
SUPPORT RIBF168
DOWNSTREAM
UPSTREAM

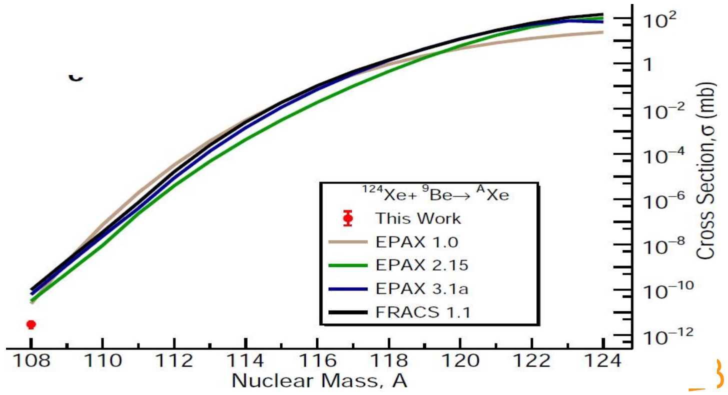
Ian Cox

^{108}Xe from ^{124}Xe fragmentation

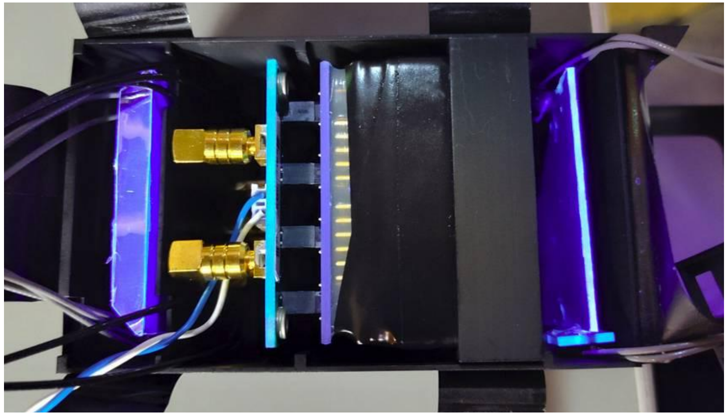
We observed 12 counts in ~120 hours (reduction factor ~30)
Estimated cross section ~2.1 fb

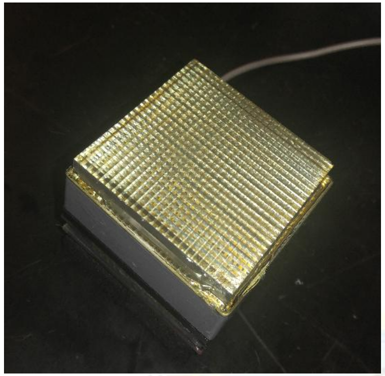


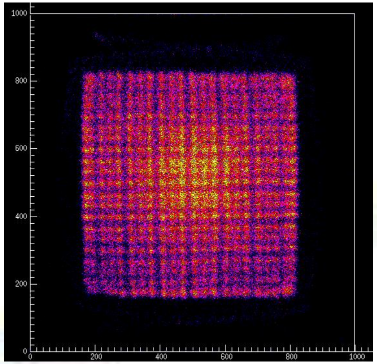


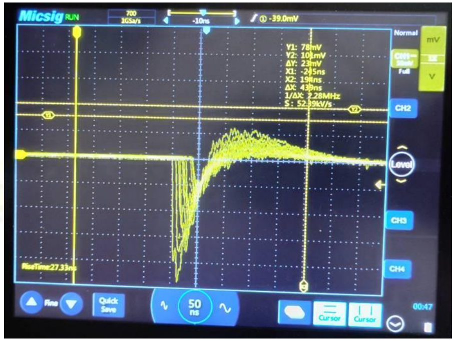


Implant detector



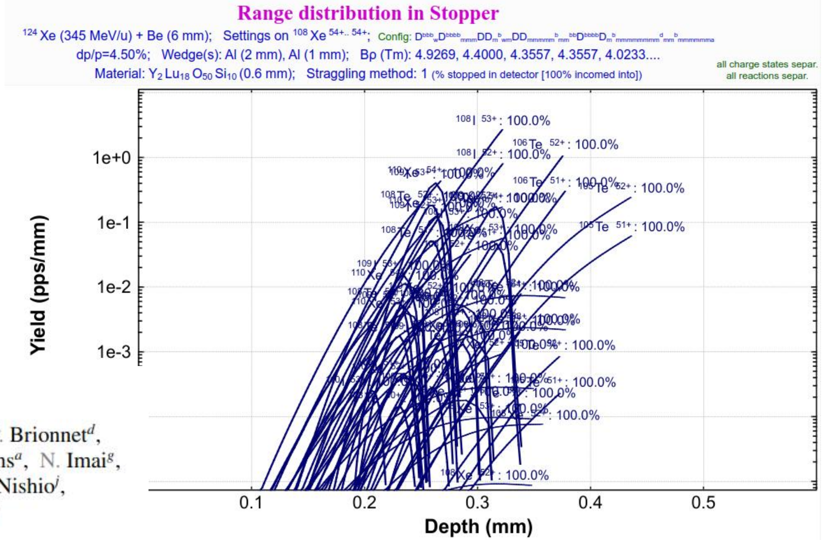






- 0.6 mm thick LYSO(Ce) 2″x2″
- 24x24x5 mm^3 segmented light guide
- H12700 segmented photomultiplier
- position sensitive readout using resistive network
- digitizer: XIA Pixie16revF, 500 MHz, 14 bit

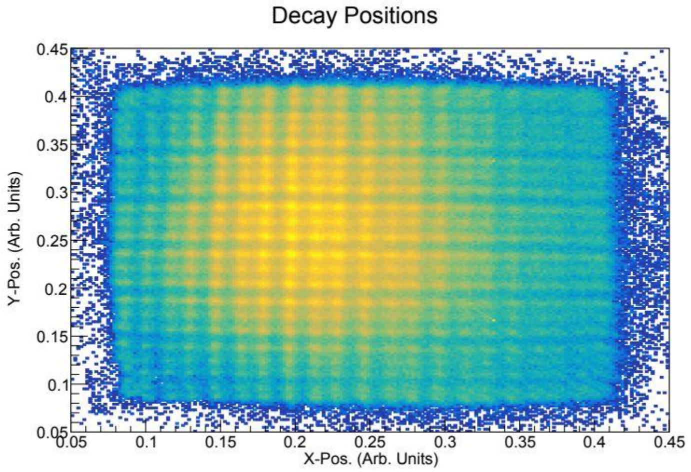
B. Kreider et al. https://arxiv.org/pdf/2508.15513

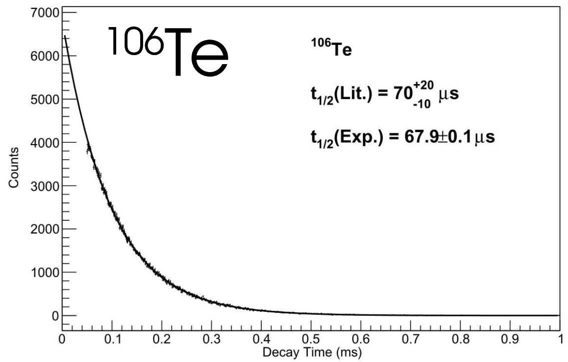


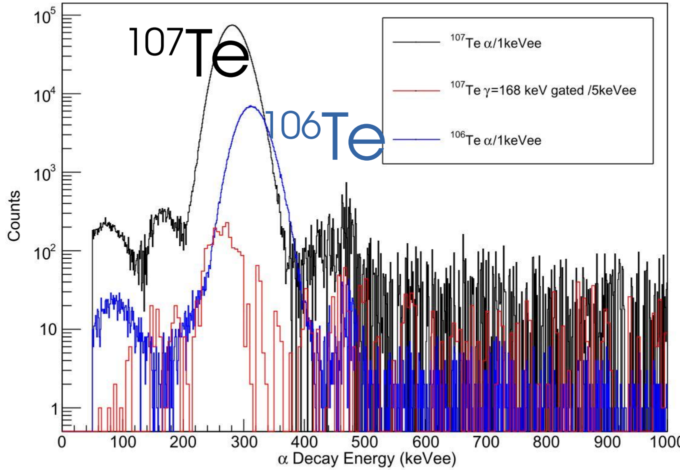
Modeling of Light Production in Inorganic Scintillators

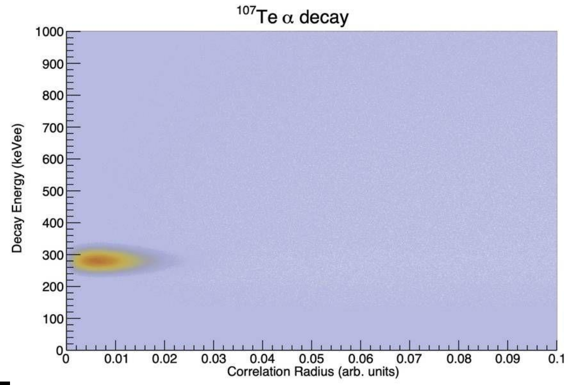
B. Kreider[a], I. Cox[a], R. Grzywacz[a], J. M. Allmond[b], A. Augustyn[c], N. Braukman[a], P. Brionnet[d], A. Esmaylzadeh[e], J. Fischer[e], N. Fukuda[d], G. Garcia De Lorenzo[f], S. Go[d,g], D. Hoskins[a], N. Imai[g], T. T. King[b], N. Kitamura[g], K. Kolos[h], A. Korgul[i], C. Mazzocchi[i], S. Nishimura[d], K. Nishio[j], V. Phong[d], T. Ruland[b], K. P. Rykaczewski[b], A. Skruch[i], Z. Y. Xu[a] and R. Yokoyama[g]

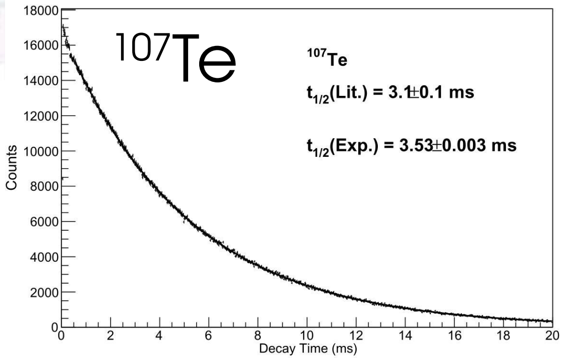
Detection of alpha particles



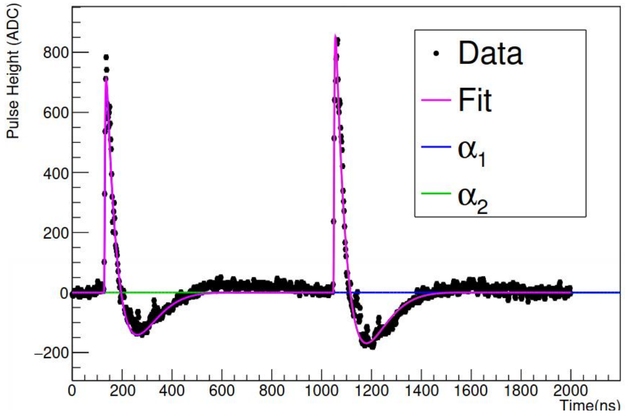






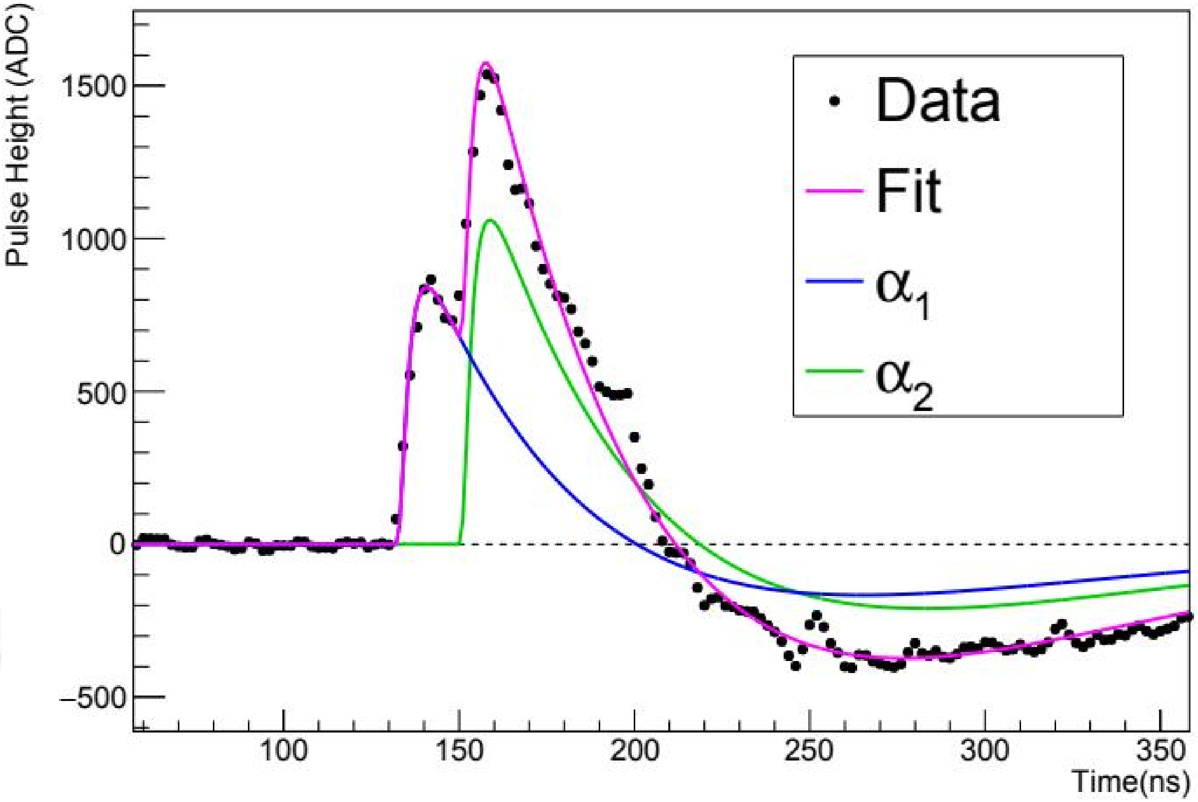


^{109}Xe → ^{105}Te → ^{101}Sn

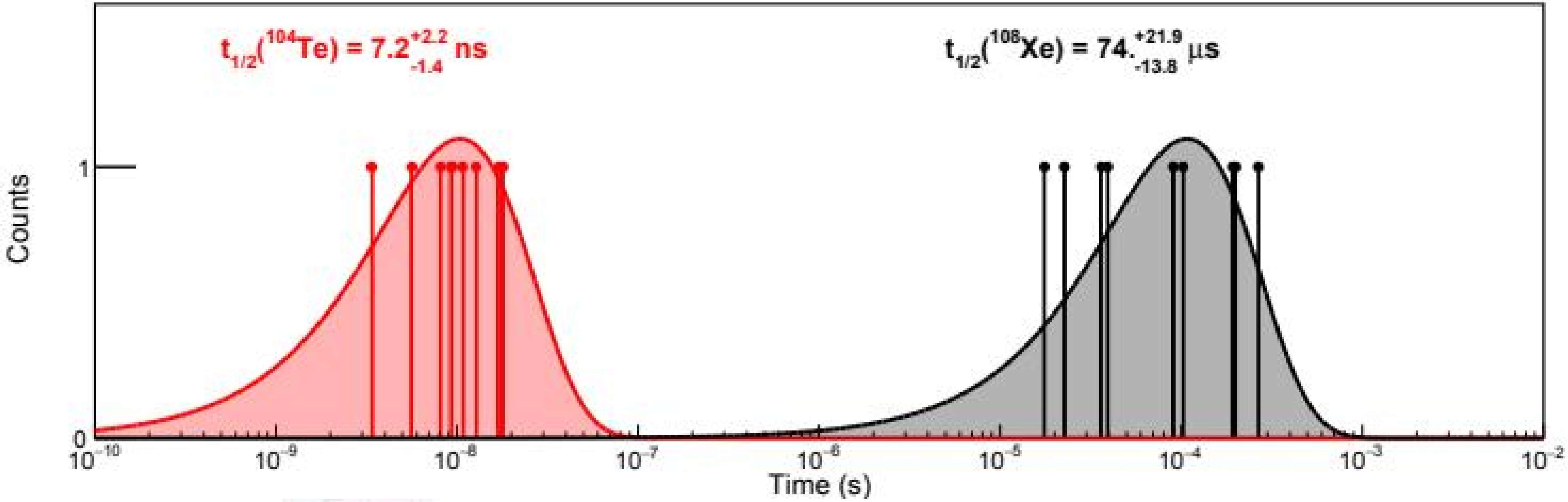


Alpha-alpha pileup signals

$^{108}Xe \rightarrow {}^{104}Te \rightarrow {}^{100}Sn$

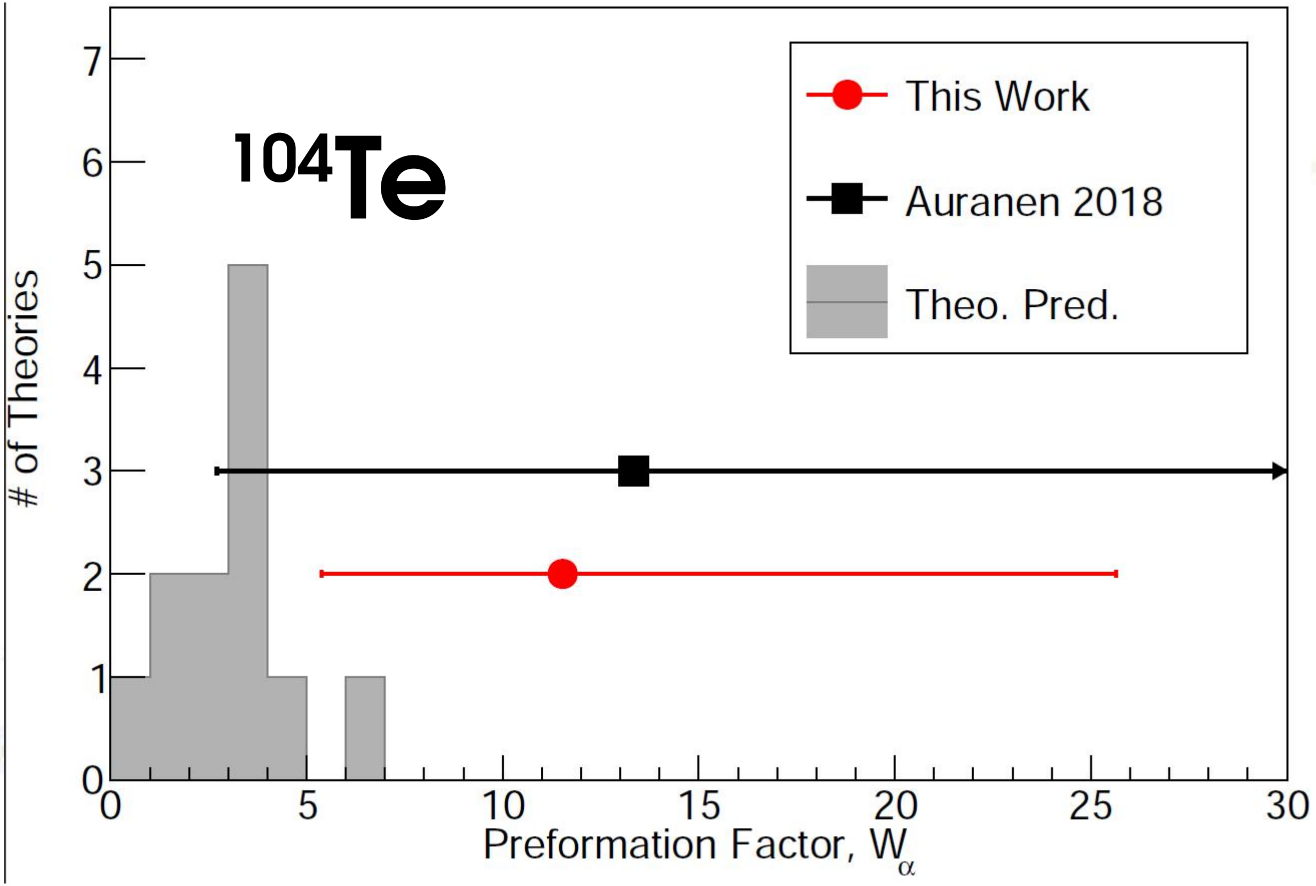


Half-life of ^{104}Te and ^{108}Xe



9 correlated events

Alpha particle pre-formation



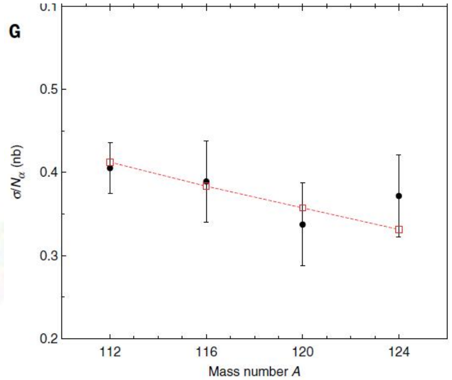
The quartetting model and alpha particle pre-formation

Quartetting wave function approach (QWFA)

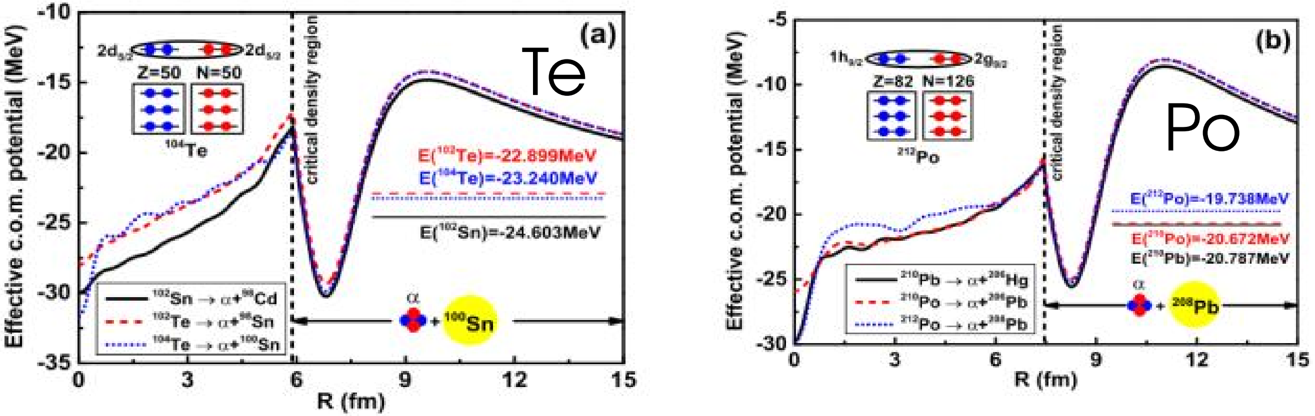
G. Roepke and P. Schuck

α-cluster can only be formed on the surface of the "core"
Inside the nucleus the α cluster dissolves and four nucleons are uncorrelated.

- Four nucleons moving in a self-consistently determined mean field, the shell model wave function determine the nuclear surface density and probability to form α-clusters (stronger for ^{104}Te than ^{212}Po).
- The (p,p′α) experiment determined the probability of cluster formation for stable neutron rich Sn isotopes.



Tanaka et al., Science 371, 260–264 (2021)



PHYSICAL REVIEW C 104, 034302 (2021)

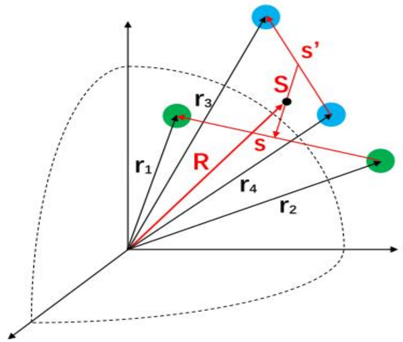
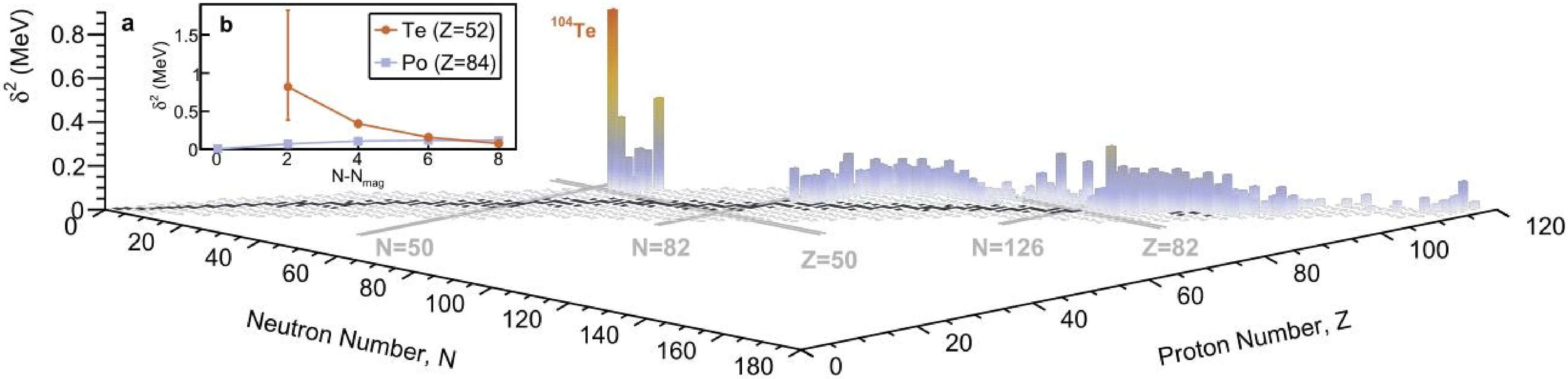


FIG. 1. A sketch of Jacobi-Moshinsky coordinates for the quartet with two protons at positions $\mathbf{r}_1 \uparrow$, $\mathbf{r}_2 \downarrow$ and two neutrons at positions $\mathbf{r}_3 \uparrow$, $\mathbf{r}_4 \downarrow$.

Shuo Yang et al., PHYSICAL REVIEW C 101, 024316 (2020)

Superallowed Alpha Decay of ^{104}Te

- ^{108}Xe produced in fragmentation of ^{124}Xe with ~1 fb cross section (12 events)
- First unambiguous observation of ^{108}Xe → ^{104}Te decay chain
- Fast response scintillator system can measure fast pileups.
- First measurement of the ^{104}Te decay half-life $7.2^{+2.2}_{-1.4}$ ns
- The Q_α value higher than expected, consistent with ANL result.
- High observed preformation (~10) compatible with QWFA predictions.



La Double Vie De Robert Janssens ?

Robert Janssens

文A 4 languages

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La Double Vie De Robert Janssens ?

Robert Janssens

4 languages

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Robert Janssens (born 1939) is a Belgian composer and conductor. He is a French-speaking member of the Union of Belgian Composers, one of whose essential missions is "to disseminate the orchestral production of our compositions".

Janssens studied at the Royal Conservatory of Liège and Brussels.[1] He initially taught at the École Normale in Brussels. He later became Professor of Orchestra Conducting at the Brussels Conservatory and Director of the Brussels Academy of Music and the Conservatoire royal de Mons [fr]. He is the founder and president of the Brussels Summer Festival [fr], which regularly presents works by contemporary Belgian composers.

Janssens mainly composed works for large orchestra, including a piano and cello concerto and the ballet *Yerma*, premiered by the Ballet royal de Wallonie [fr], but also piano works and several string quartets. Among his religious works, the Mass of the artistes is particularly noteworthy, as is the Requiem, which was celebrated with standing ovations at its premiere in Brussels in 2004.

He is the permanent conductor of the Ensemble symphonique de Bruxelles.

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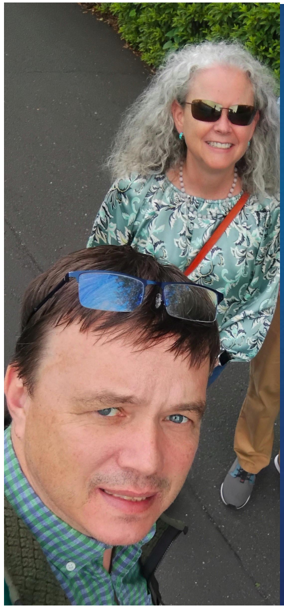
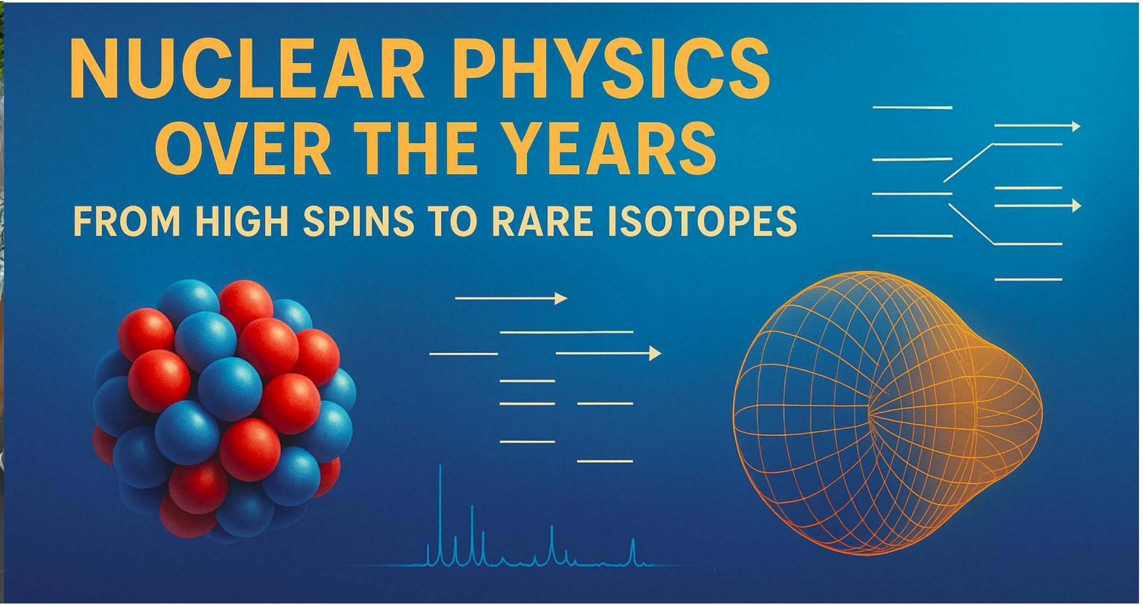
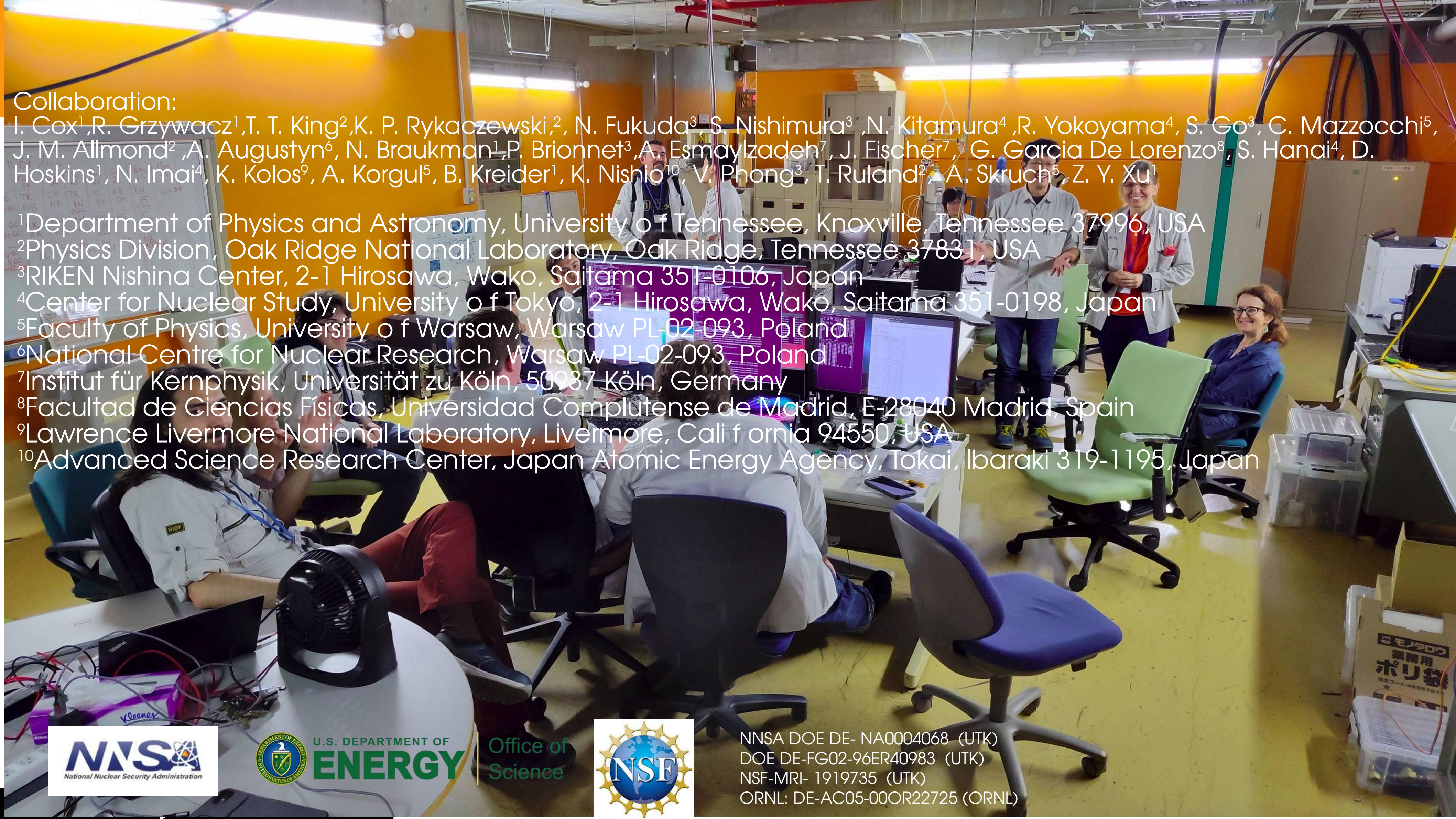
La Double Vie De Robert Janssens ?

Happy retirement Robert !

from Kate and myself



Collaboration:
I. Cox[1],R. Grzywacz[1],T. T. King[2],K. P. Rykaczewski,[2], N. Fukuda[3], S. Nishimura[3] ,N. Kitamura[4] ,R. Yokoyama[4], S. Go[3], C. Mazzocchi[5], J. M. Allmond[2] ,A. Augustyn[6], N. Braukman[1],P. Brionnet[3],A. Esmaylzadeh[7], J. Fischer[7], G. Garcia De Lorenzo[8], S. Hanai[4], D. Hoskins[1], N. Imai[4], K. Kolos[9], A. Korgul[5], B. Kreider[1], K. Nishio[10], V. Phong[3], T. Ruland[2], A. Skruch[5], Z. Y. Xu[1]

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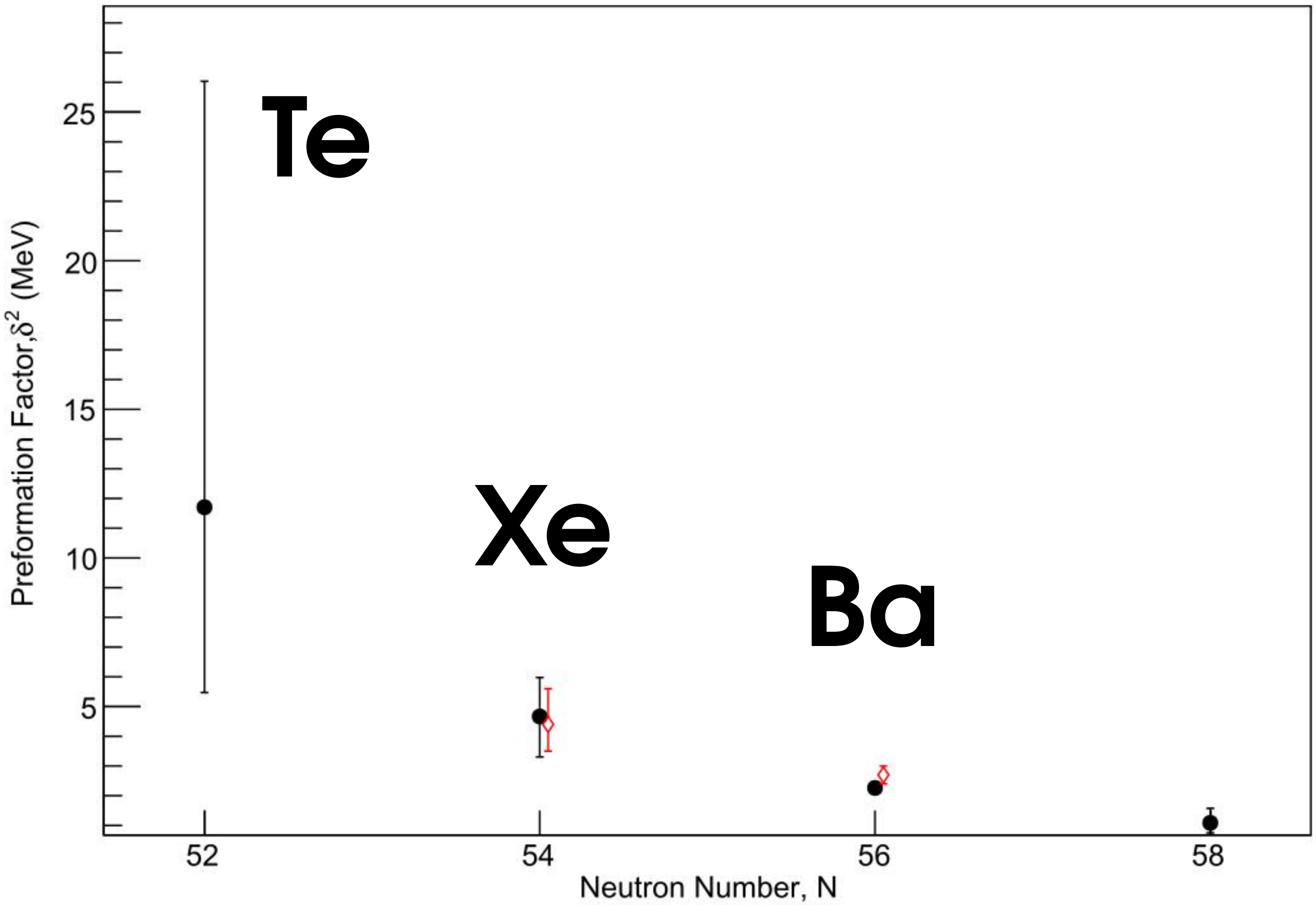
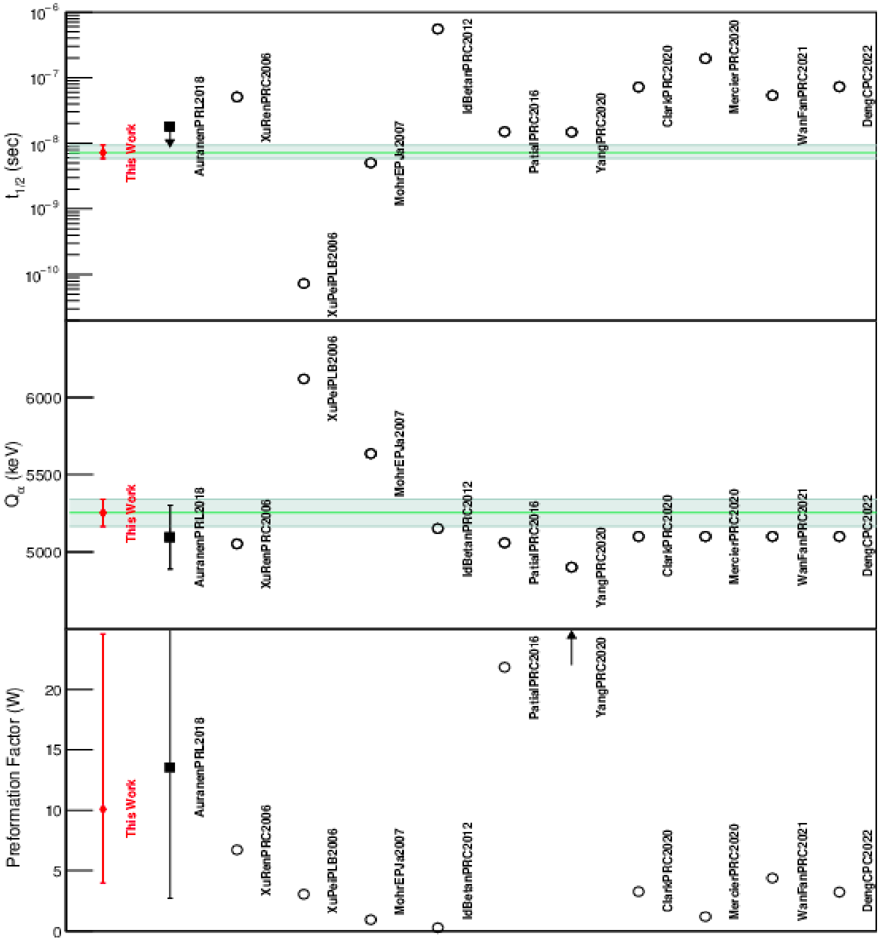
NNSA DOE DE- NA0004068 (UTK)
DOE DE-FG02-96ER40983 (UTK)
NSF-MRI- 1919735 (UTK)
ORNL: DE-AC05-00OR22725 (ORNL)

Z=82
N=126
Z=50
N=82
Z=28
Z=20
N=50
Z=8
N=28
N=20
N=8

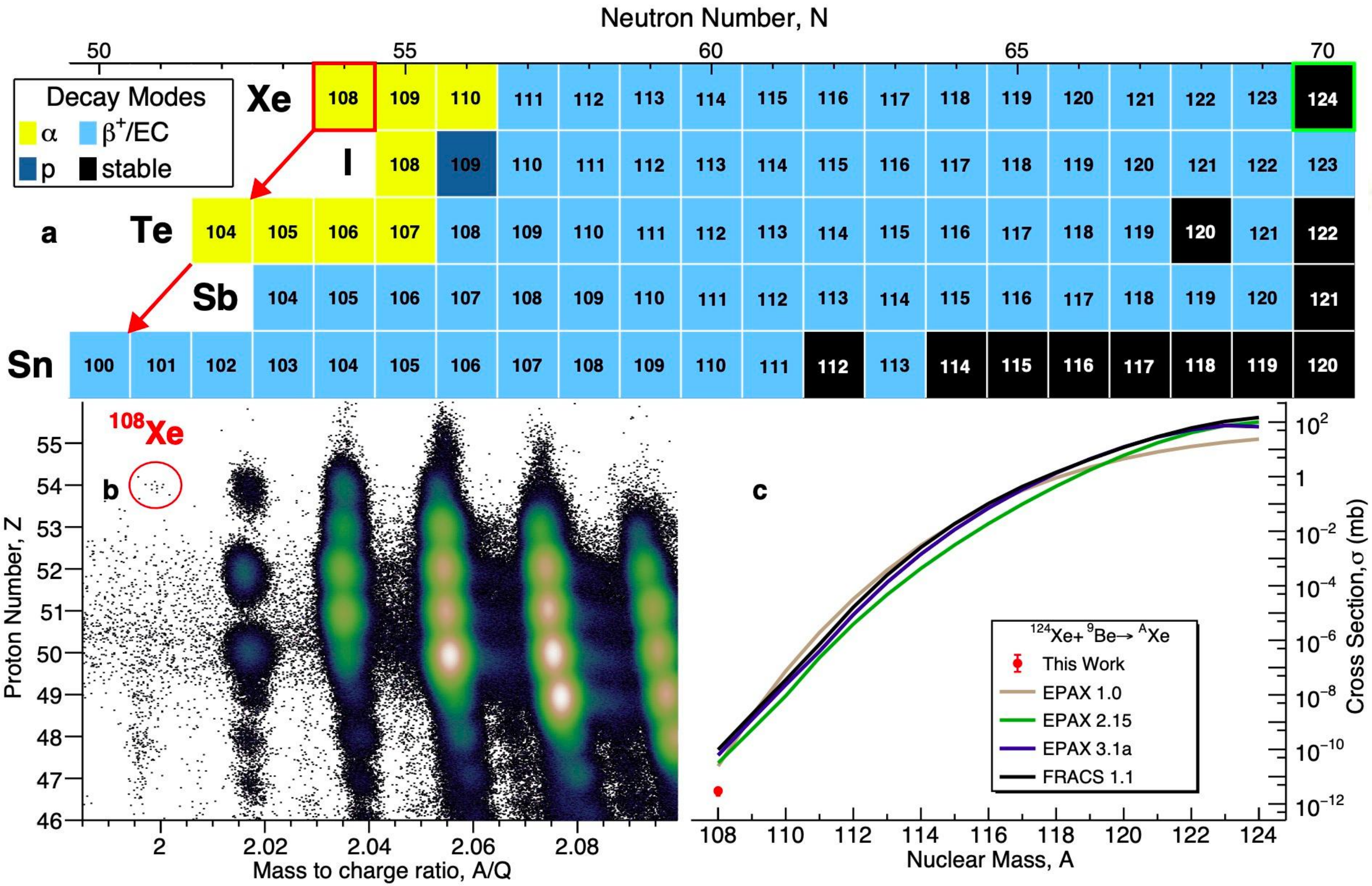
Alpha particle pre-formation

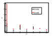


$T_{1/2}$, Q_α and W_α of ^{104}Te – experiment and theory



^{108}Xe from ^{124}Xe fragmentation





^{104}Te

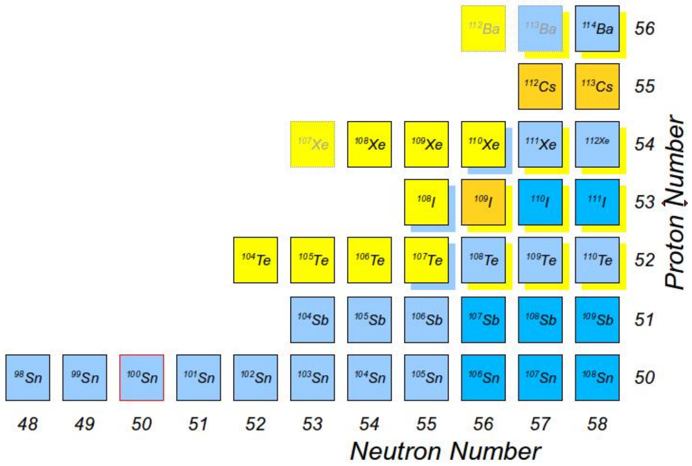
^{106}Te

^{105}Te ^{110}Xe ^{112}Xe ^{109}Te

^{107}Te ^{110}Te

^{108}Te

^{108}Xe ^{109}Xe ^{111}Xe



The quartetting model and alpha particle pre-formation

Quartetting wave function approach (QWFA)

G. Roepke and P. Schuck

a-cluster can only be formed on the surface of the "core"
Inside the nucleus the a cluster dissolves and four nucleons are uncorrelated.

- Four nucleons moving in a self-consistently determined mean field, the shell model wave function determine the nuclear surface density and probability to form a-clusters (stronger for ^{104}Te than ^{212}Po).
- The (p,p'a) experiment determined the probability of cluster formation for stable neutron rich Sn isotopes.

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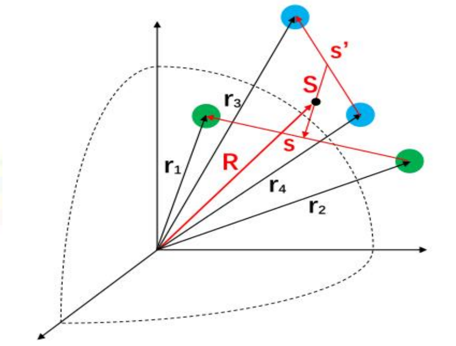
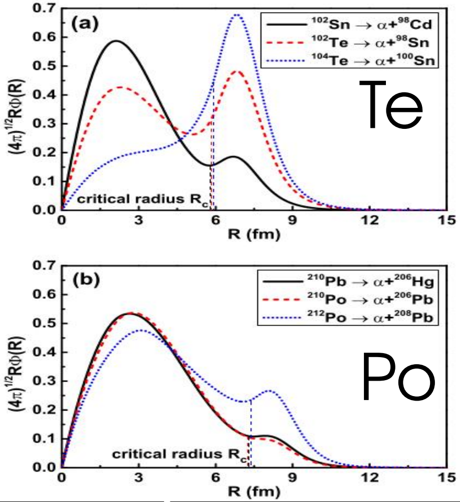
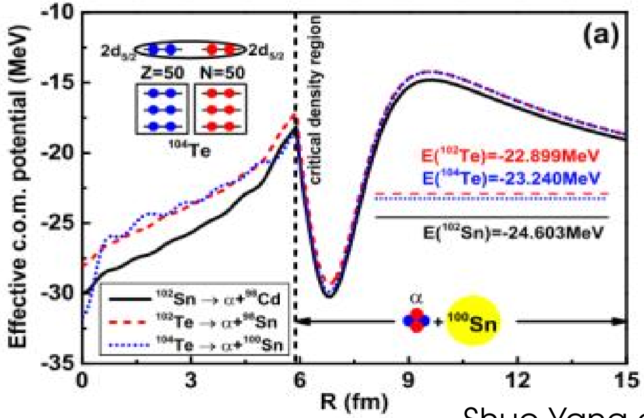
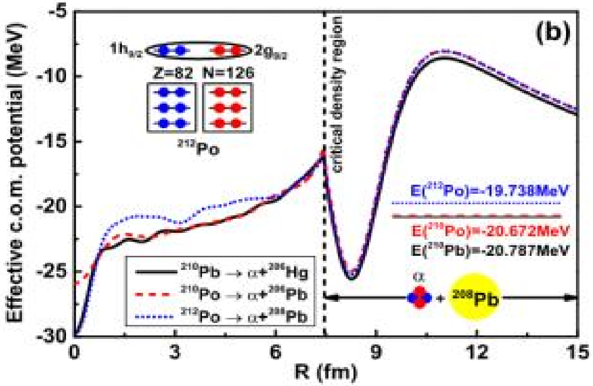


FIG. 1. A sketch of Jacobi-Moshinsky coordinates for the quartet with two protons at positions $\mathbf{r}_1 \uparrow, \mathbf{r}_2 \downarrow$ and two neutrons at positions $\mathbf{r}_3 \uparrow, \mathbf{r}_4 \downarrow$.

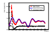


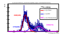
Tanaka et al., Science 371, 260–264 (2021)

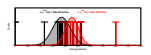




Shuo Yang et al., PHYSICAL REVIEW C 101, 024316 (2020)







Z=8
N=28
N=20
N=8