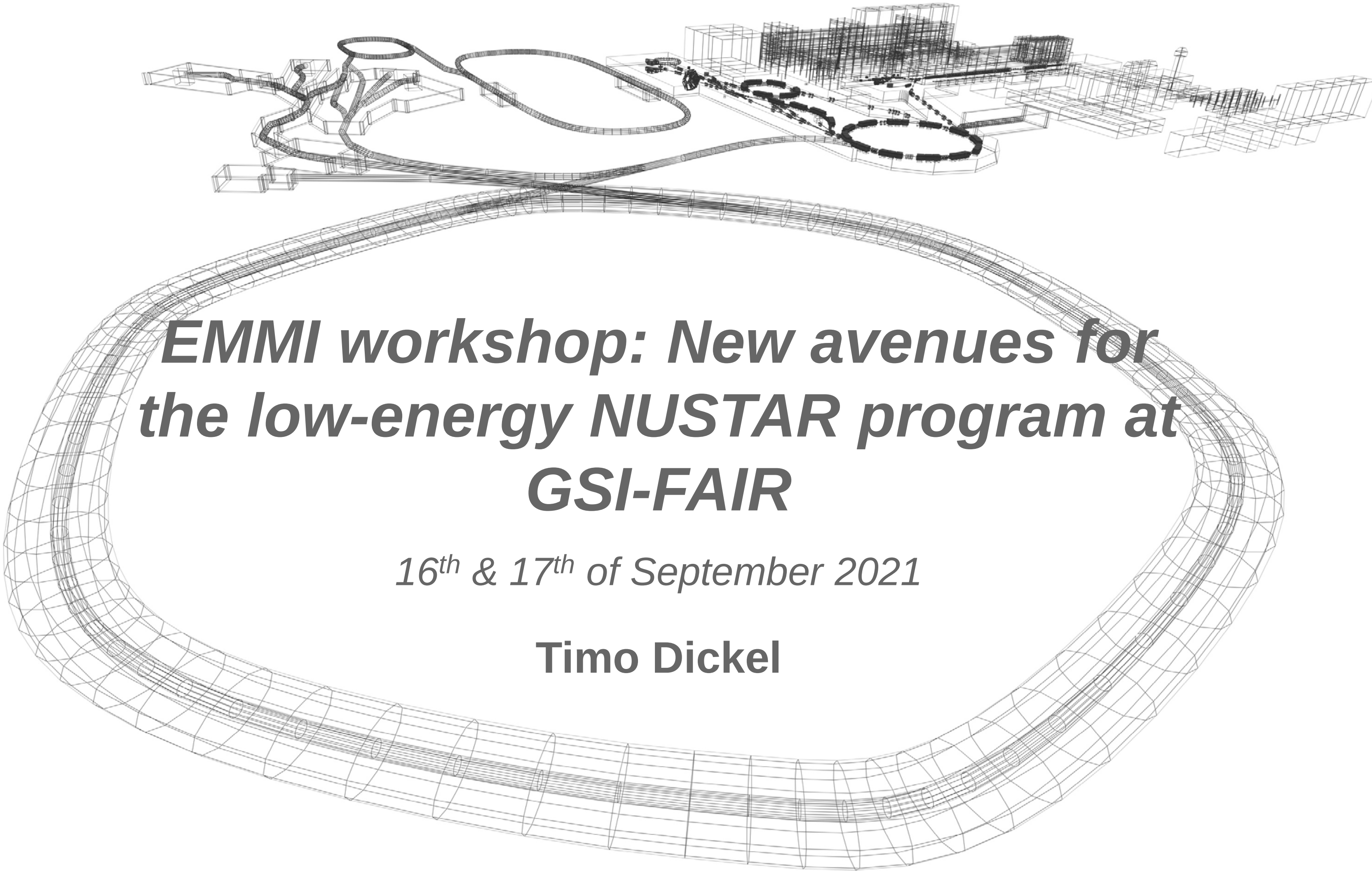


EMMI workshop: New avenues for the low-energy NUSTAR program at GSI-FAIR

16th & 17th of September 2021

Timo Dickel

Programm

Th.		Speaker	Topic
Session 1		Chair	W. Korten
09:00	00:15	P. Giubellino	Welcome and Scope of the Worksh
09:15	00:30	W. Barth	Existing and future (he at GSI
09:45	00:30	HJ Wollersheim	History of eriments at UNILAC
10:15	00:20	S. Kraft-Bermuth	Ex meters for heavy ions at the
10:35	00:20	E. Vardaci	dies with a kinematic TOF method
10:55	**00:30**	**coffee break**	
Session 2		Chair	N. Kalantar
11:25	00:30	G. Martinez-Pinedo	r-process nucleosynth n star mergers
11:55	00:30	I. Dedes	Exotic Shape In : Tracing Unexpected
12:25	00:30	V. Saiko	Synthesis of neu ed nuclei near closed neutron
12:55	**01:15**	**lunch break**	
Session 3		Chair	D. Rudolph
14:10	00:30	H. Albers	Probing the structure of 208Pb and Hf with UNILAC
14:40	00:30	M. Gorska	Spin gap isomers as a too n-neutron
15:10	00:20	L. Sarmiento	Spectroscopy c dium decay station
15:30	00:20	R. Palit	Nuclear structu ght particle tagging
15:50	**00:30**	**coffee break**	
Session 4		Chair	A. Karpov
16:20	00:30	T. Dickel	Future plans MNT reactions at GSI/FAIR
16:50	00:20	M. Brodeur	The N=126 factory at AN
17:10	00:20	Z. Favier	MNT experiment c onne: 136Xe+238U at 0°
17:30	00:15	R. de Groote	Opportunties for las oscopy with MNT reaction
18:30		**Reception**	

Past, present and near future

Theory

Reaction

MNT

Fr.		Speaker	Topic
Session 5		Chair	A. Bruce
09:00	00:30	K. Wimmer	Shape coexistence and nuclear ersion electron
09:30	00:20	D. Kumar	Investigation of Rare s via mass
09:50	00:20	A. Zadvornaya	Science pr of MNT reaction studies
10:10	00:30	Z. Chen	Inve ch isotopes around N=126 using
10:40	**00:20**	**coffee break**	
Session 6		Chair	D. Ackermann
11:00	00:30	P. Walker	n-rich high-K isomers in the hafni gion
11:30	00:20	A. Stuchbery /	Is in-beam spectroscop Unilac? Precise g factor
11:50	00:20	P. Reiter	Ground state sition metals to
12:10	00:20	O. Hall	beta-de utilising Multi-Nucleon-Transfer
12:30	**01:00**	**lunch break**	
Session 7		Chair	C. Scheidenberger
13:30	00:15	T. Dickel	Summary presentation
13:45	00:45		Discussion: how to move forward
14:30			End of Workshop

Cases Z ~< 82

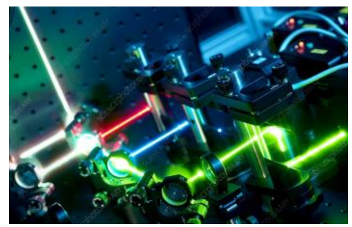
Cases ~238U

23 presentations
176 registrations
26 countries
>70 instituts

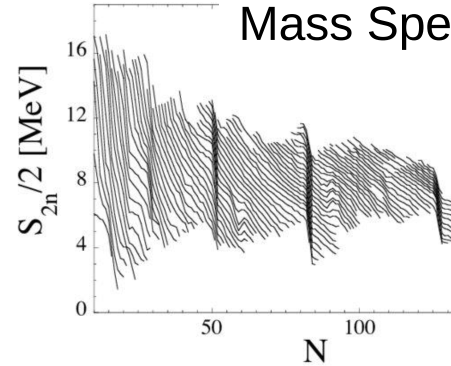
Topics

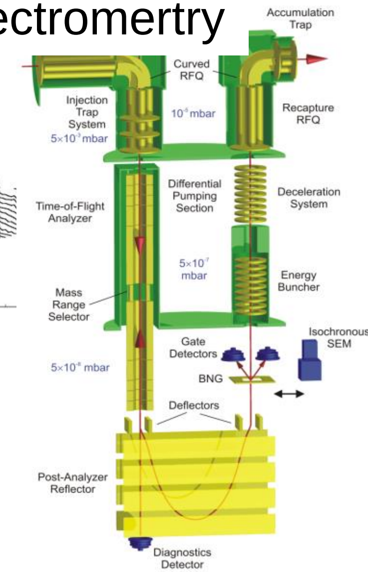
Nuclear Astrophysics

Laser Spec.

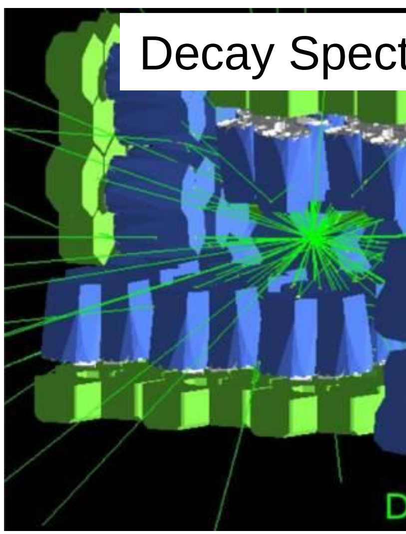


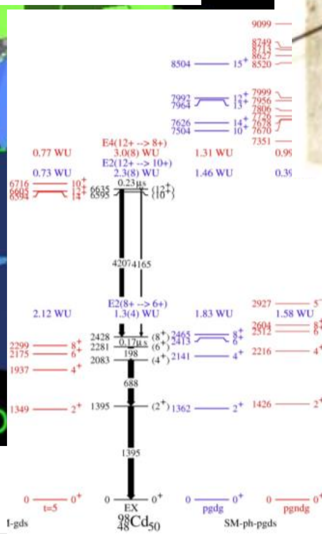
Mass Spectromertry

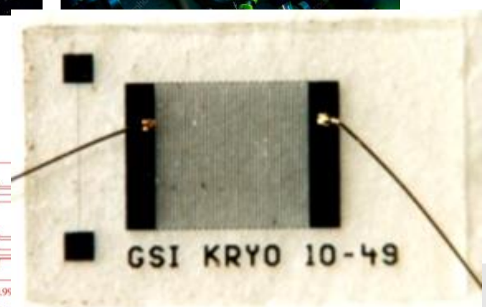




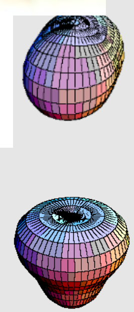
Decay Spectroscopy



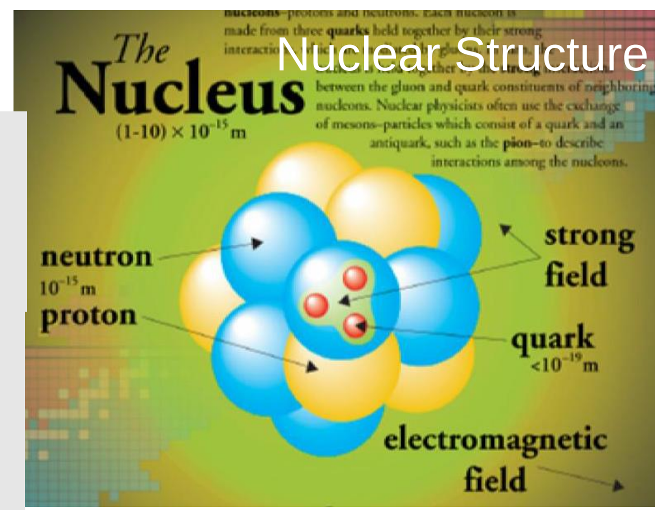




Detector Development



Nuclear Structure



Beams at the UNILAC/HELIAC (W. Barth)

FAIR:

2025?

- high beam currents
- low repetition rate (max. 3 Hz)
- low duty factor (0.1 %, pulse length for SIS18 only 100 µs)

FAIR-design uranium beam parameters at the UNILAC

	HSI entrance	HSI exit	Alvarez entrance	SIS 18 injection
Ion species	$^{238}U^{4+}$	$^{238}U^{4+}$	$^{238}U^{28+}$	$^{238}U^{28+}$
Elect. Current [mA]	25	18	15	15.0
Part./100µs pulse	$3.9 \cdot 10^{12}$	$2.8 \cdot 10^{12}$	$3.3 \cdot 10^{11}$	$3.3 \cdot 10^{11}$
Energy [MeV/u]	0.0022	1.4	1.4	11.4
$\Delta W/W$	-	$4 \cdot 10^{-3}$	$\pm 1 \cdot 10^{-2}$	$\pm 2 \cdot 10^{-3}$
$\varepsilon_{norm.,x}$ [mm mrad]	0.3	0.5	0.75	1.0
$\varepsilon_{norm.,y}$ [mm mrad]	0.3	0.5	0.75	2.5

2029?

18 GHz ECR ion source (Jyväskylä)

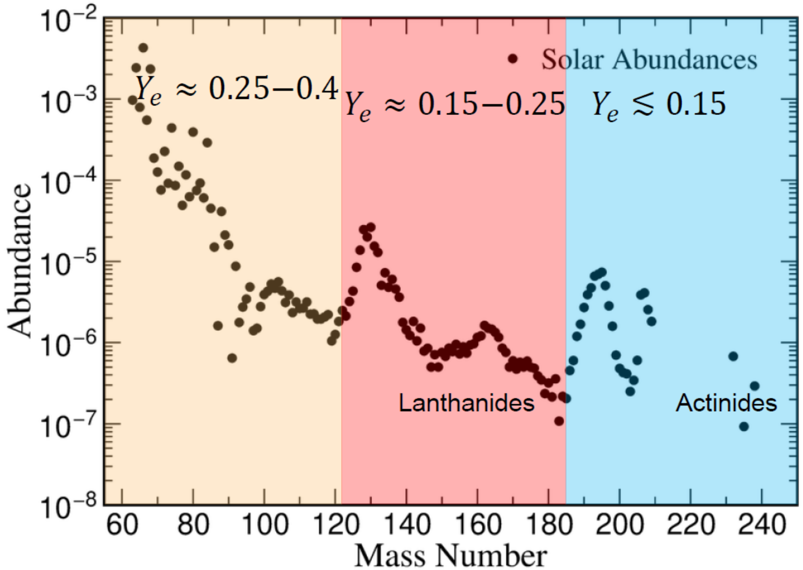
		ion source		low energy		high energy			
ion species	ion current	Z	A/Z	Z_{low}	A/Z_{low}	Z_{high}	A/Z_{high}		
H_3 (HIT-ECR, 8keV/u)	700eµA	1+	2.0	p+	1.0	p+	1.0		
^{40}Ar	330eµA	13+	3.1	13+	3.1	18+	2.2		
^{40}Ar	680eµA	11+	3.6	11+	3.6	18+	2.2		
^{84}Kr (57%)	120eµA	25+	3,4	25+	3,4	34+	2.5		
^{132}Xe	1eµA	44+	3.0	44+	3.0	48+	2.75	10.9 MeV/u	(5×10^{6})
^{132}Xe	350eµA	26+	5.1	26+	5.1	44+	3.0	8.2 MeV/u	3×10^{9}
^{197}Au**	>>15eµA	31+	6.4	31+	6.4	56+	3,5	6.9 MeV/u	$\approx5\times10^{8}$
^{206}Pb** (afterglow)	>100eµA	34+	7.2	34+	7.2	63+	3.2	7.2 MeV/u	$\approx 2\times10^{9}$
^{238}U***	???	???		35+	6.8	64+	3.7	6.6 MeV/u	-

R-process (G. Martinez-Pinedo)

Nucleosynthesis dependence on Y_e

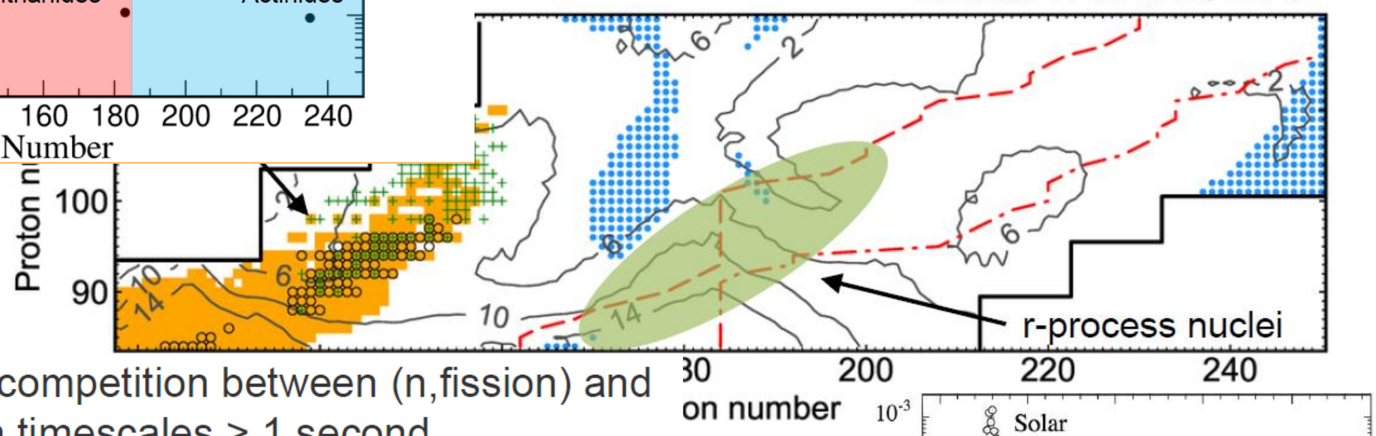
Mergers produce broad range of neutron rich ejecta, $Y_e = n_p/(n_n + n_p)$

$\nu_e + n \rightleftarrows p + e^-$ vs $\bar{\nu}_e + p \rightleftarrows n + e^+$



- Ye=0.4-0.34, 1st r-process peak (observed Sr)
  - Competition (α,γ), (α,n), (n,γ) and β-decay in the region around ^{78}Ni
- Ye=0.34-0.2, 2nd and 3rd r-process peak
  - (n,γ) and β-decay
- Ye<0.2, 2nd, 3rd r-process peaks and actinides
  - (n,γ) and β-decay and fission

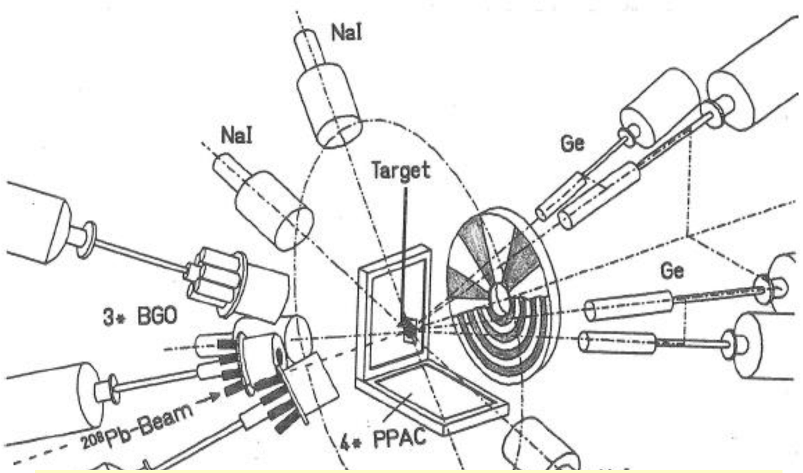
Giuliani et al 2018, 2020

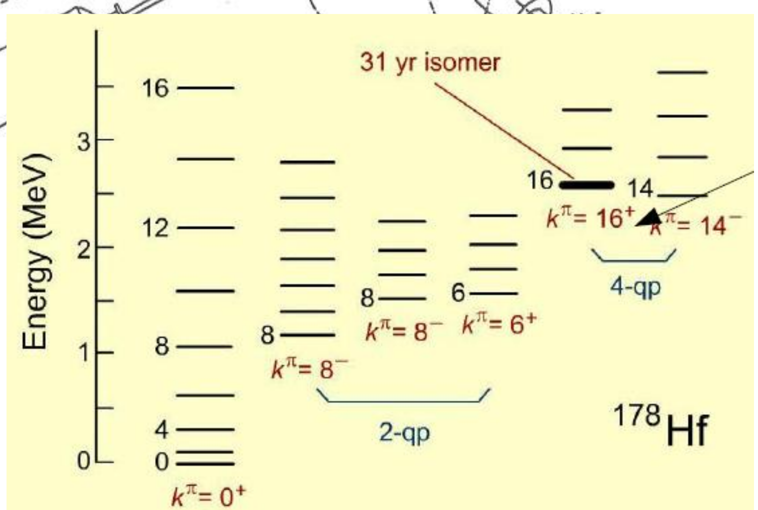


- 254Cf is produced by a competition between (n,fission) and beta-decay operating on timescales > 1 second
- No experimental information about the beta half-lives of he progenitors is known. Strong impact on radioactive heating

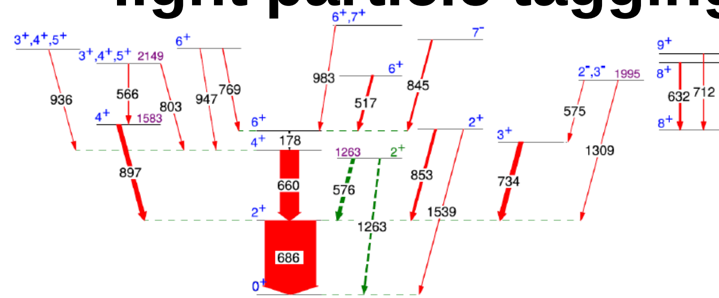
In-beam Spetroscopy (Exp.: H.J. Wollersheim / H. Alberts / R. Palit / A. Stuchbery| Theory: I. Dedes)

Searches for 2-phonon octupole excitations in ^{208}Pb

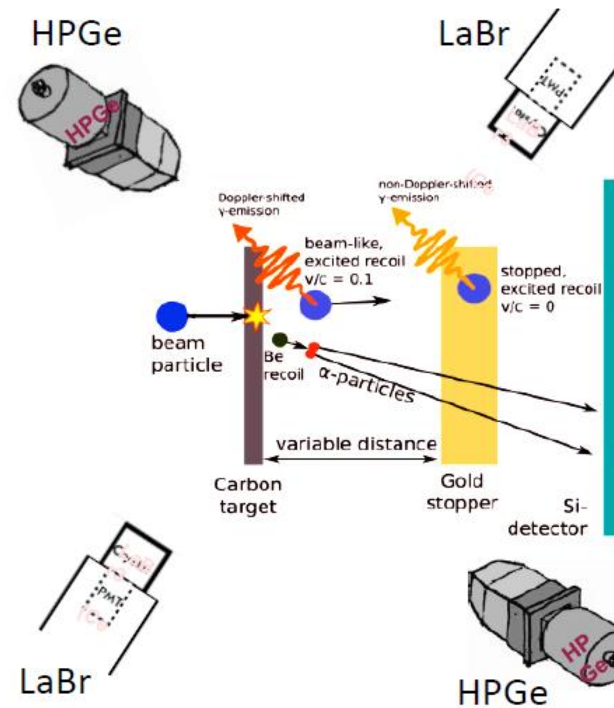




light particle tagging

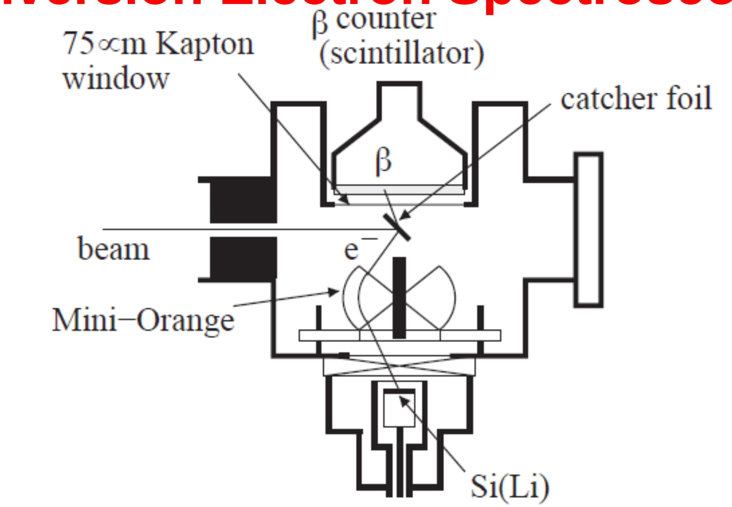


A. Yaneva et al. EPJA56 246 (2020)

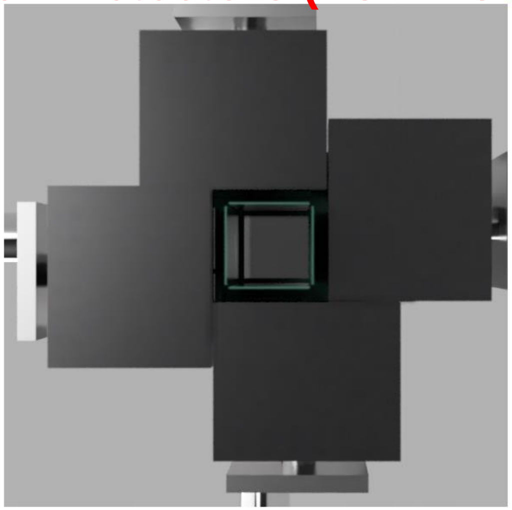


Decay Spectroscopy (K. Wimmer, LG. Sarmiento, O. Hall)

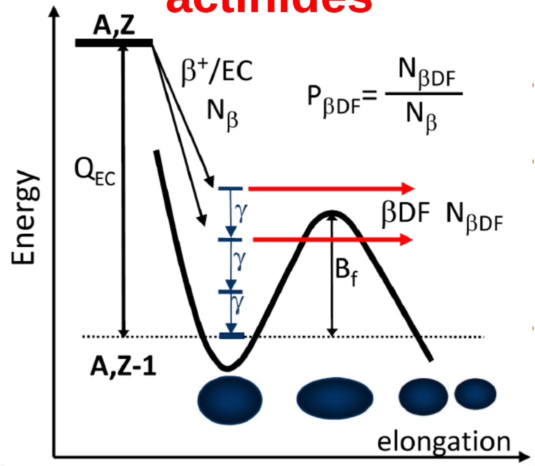
Conversion Electron Spectroscopy



New Detectors (LUNDIUM)



Beta-delayed fission of neutron-rich actinides



Isomer spectroscopy (M. Gorska, P. Walker)

The search for the missing spin gap isomers

N~Z

- Fusion symmetric reaction, high spins

EXOGAM, EUROBALL, GASP.. + Ancillaries
- in-beam, seniority/core excited isomers

MSEP at GSI, IGISOL, LISOL
- β decay
- spin-gap isomers

Argonne, OakRidge
- α-decay

N>>Z

- Deep Inelastic Reaction(spins up to ~30ħ) /Fission (<20ħ)

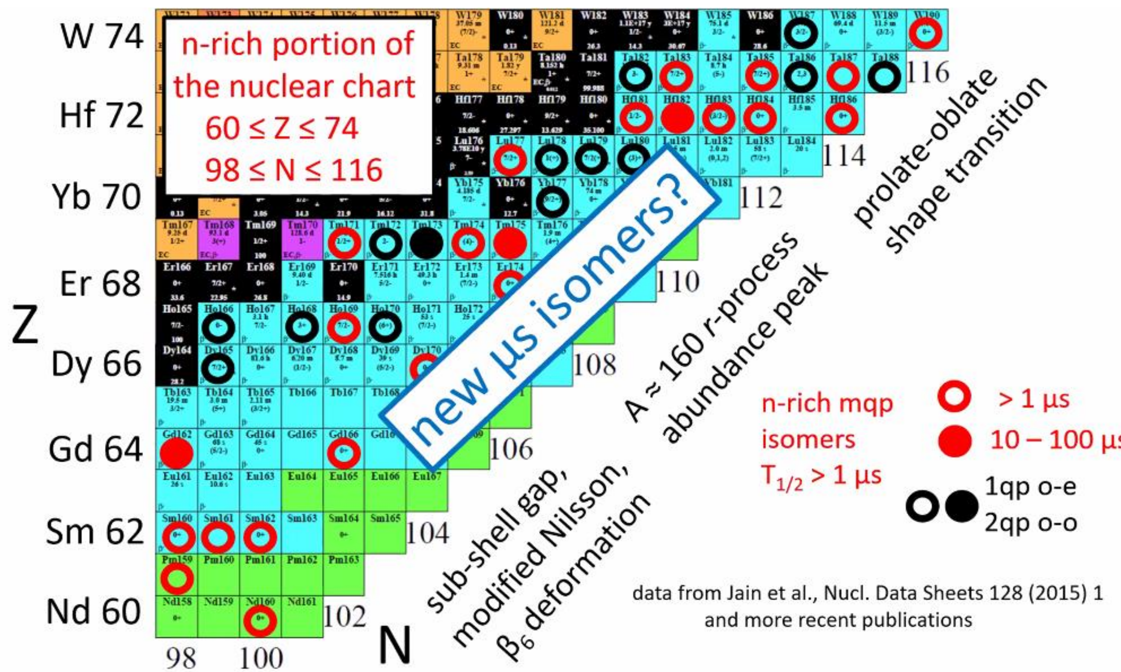
EXOGAM, EUROBALL, GASP.. + Ancillaries
- in-beam, seniority/core excited isomers

- Fragmentation, Spallation (spins <20)

GSI, RIBF, NSCL, GANIL, REX-ISOLDE
- Coulex
- Transfer
- Isomers

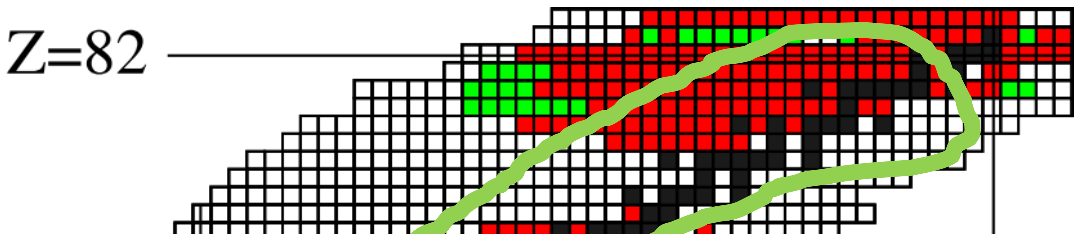
=> Optimize :
spin,
production,
selectivity

Pulsed beams for (μs) K-Isomer search

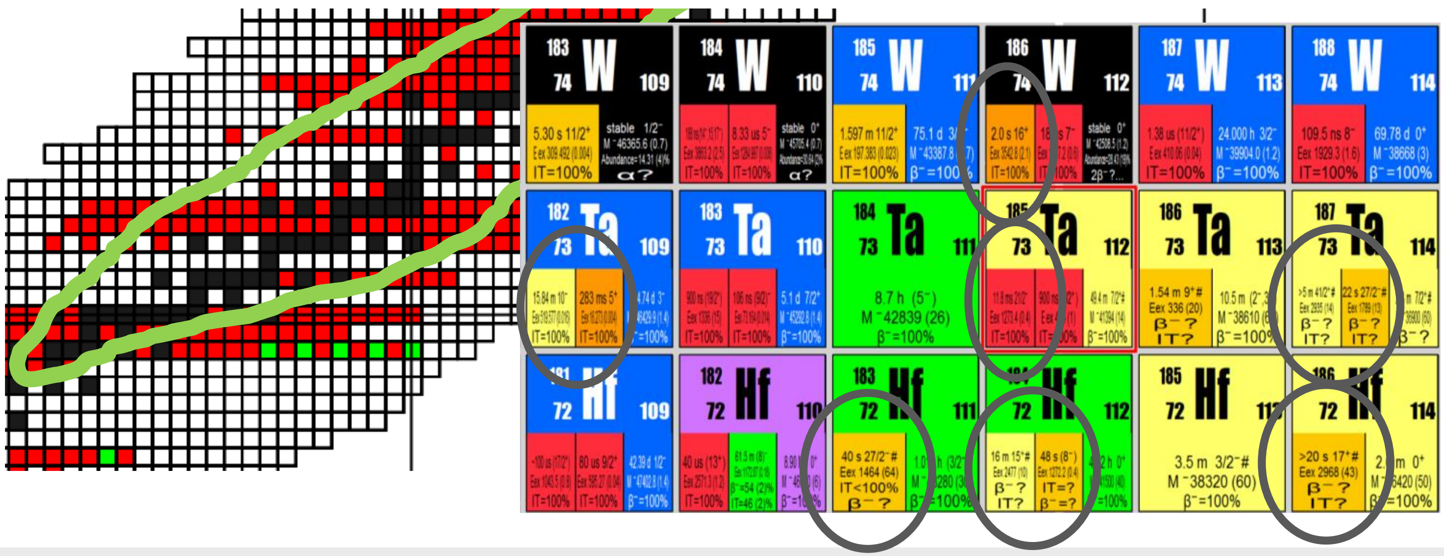


Laser Spectroscopy (R. de Groote)
Radioactive Molecules)MP. Reiter)

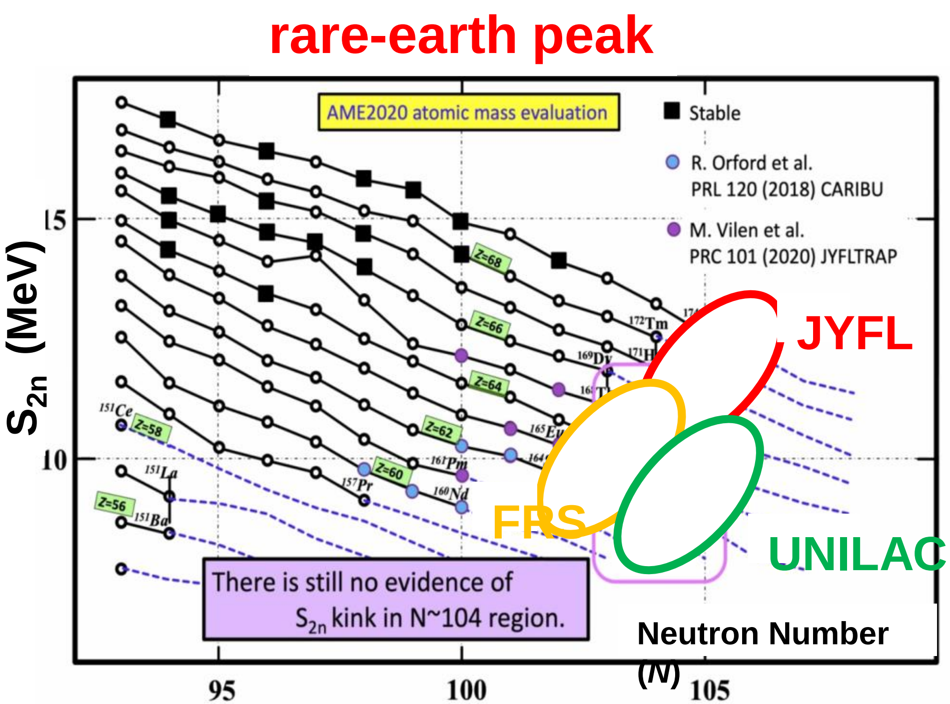
Expand EDM / BSM searches to other actinides

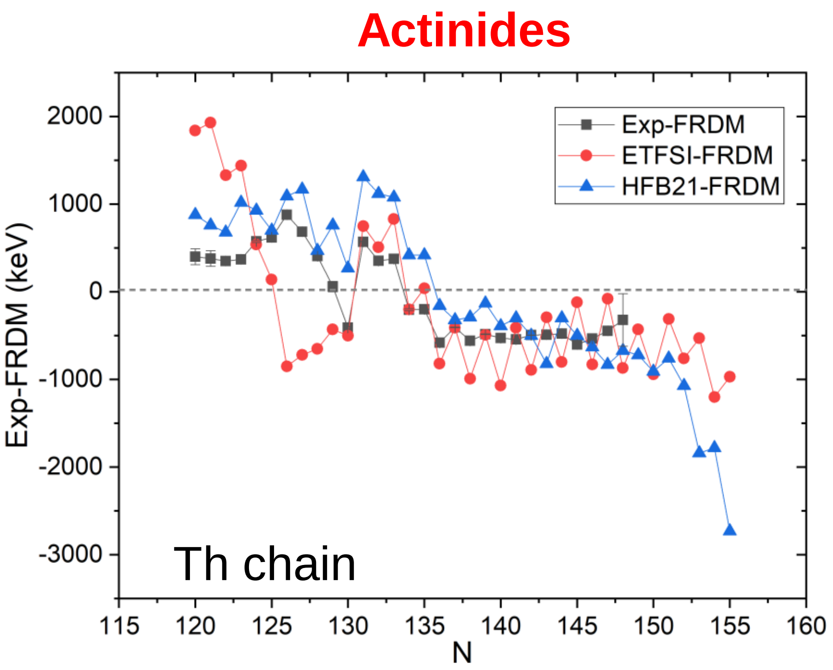


millisec high spin isomers in refractory elements



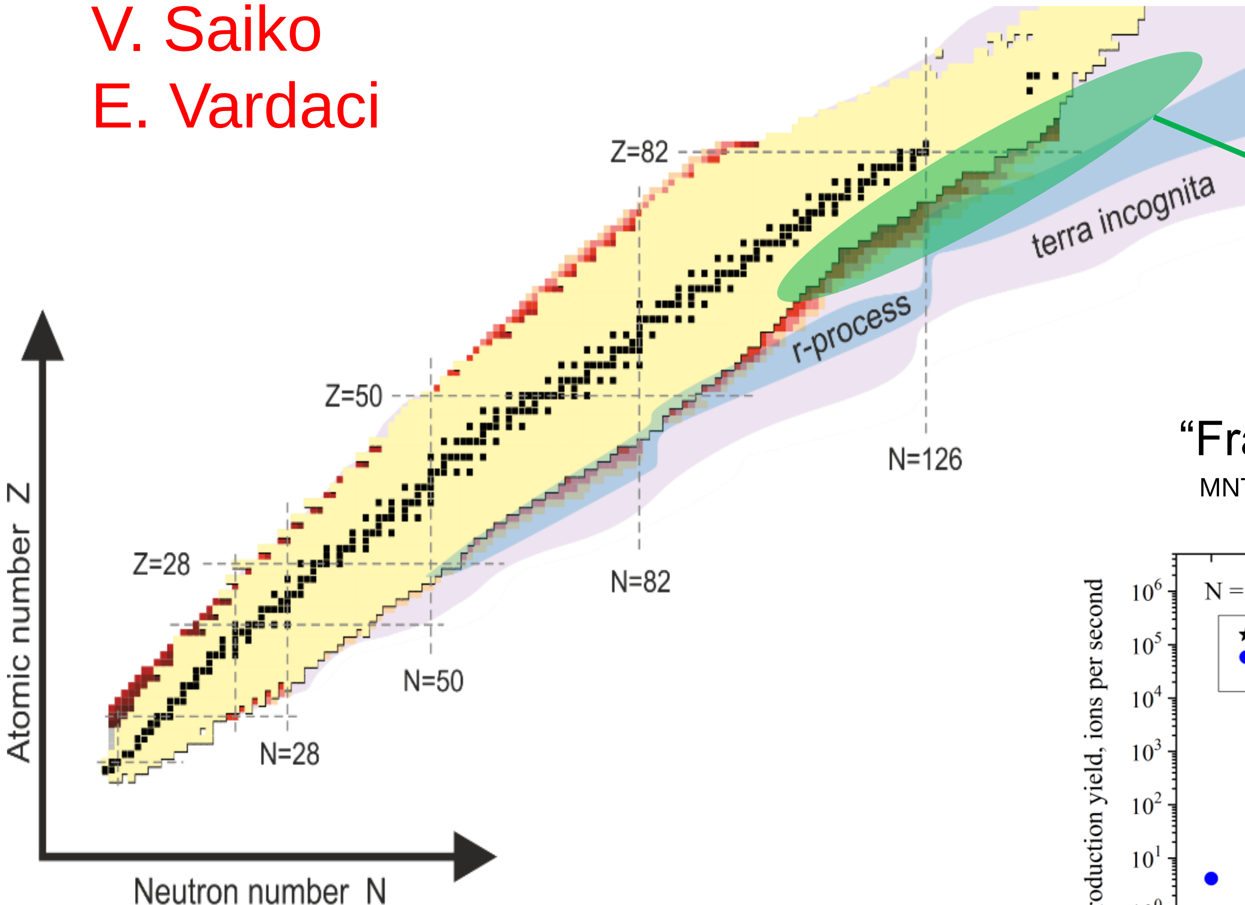
Mass spectrometry (D. Kumar, M.P. Reiter)





Explore the optimal conditions to produce new nuclei in the Terra Incognita?

V. Saiko
E. Vardaci

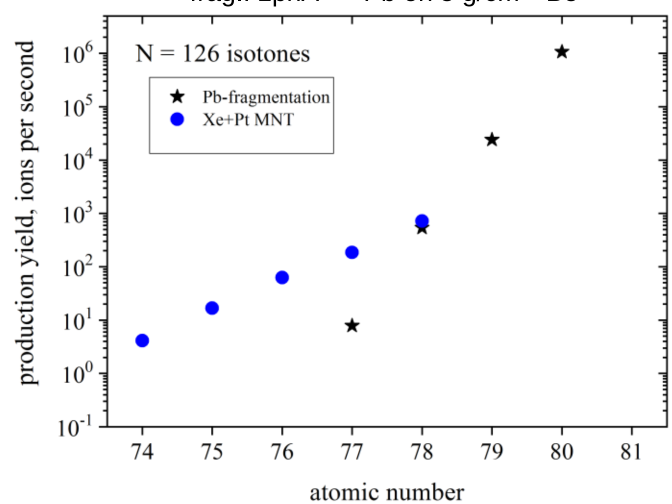


Hard or impossible to reach with fragmentation or fusion of stable beams

"Fragmentation vs. MNT"

MNT: 20pnA ^{136}Xe / ^{238}U on 2 mg/cm² ^{198}Pt

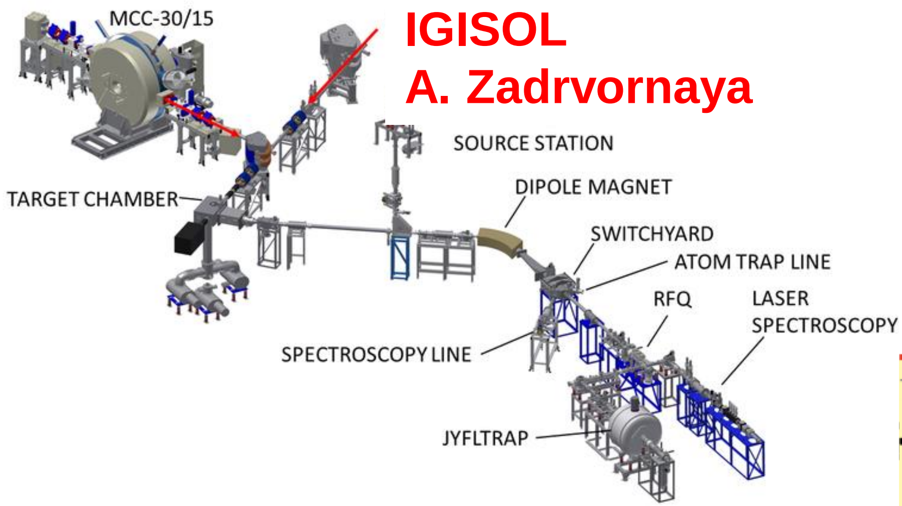
frag.: 1pnA ^{208}Pb on 5 g/cm² ^{9}Be

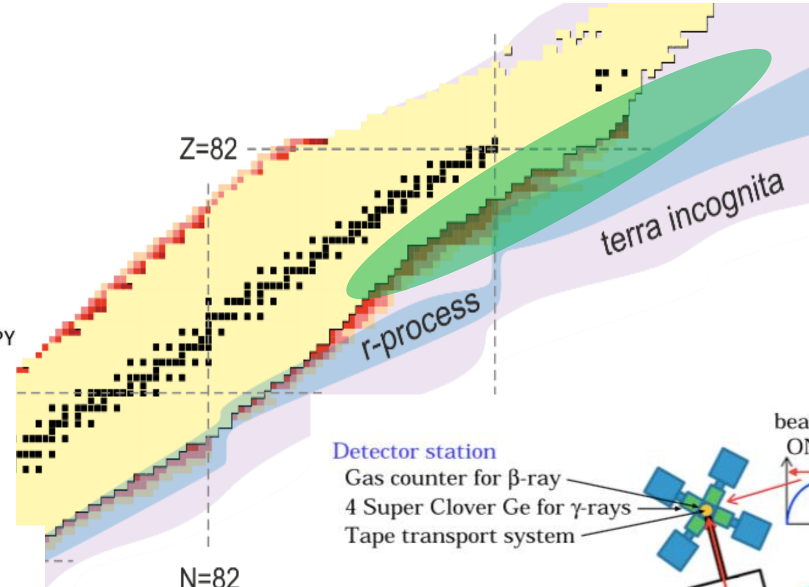


Y. X. Watanabe et al., PRL115, 1–5 (2015)

MNT experiments world-wide

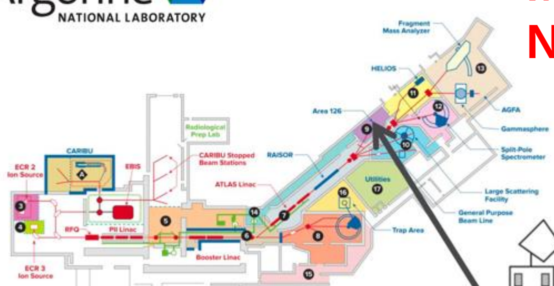
IGISOL
A. Zadrvornaya



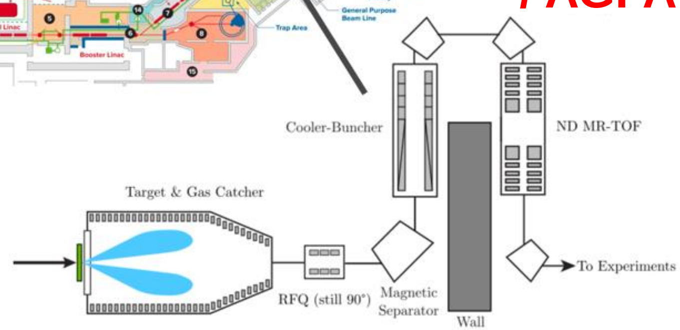


Argonne NATIONAL LABORATORY

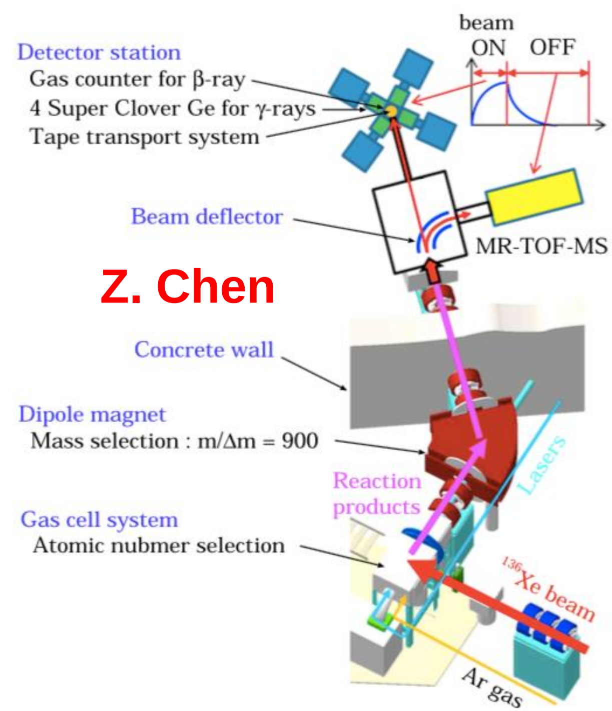
M. Brodeur
N126 factory



Z. Favier
/ AGFA



Z. Chen



Strategy for MNT experiments at GSI/FAIR

today ~2025 FAIR Phase 1 (~2030 →)

UNILAC	**Investigation optimal stable beam, energy and target** Reaction Studies with **"CORSET"** eg. U323 **LINAC Ion Catcher (^{238}U, heavy products)** mass spectrometry new isotopes nuclear spectroscopy
FRS	**Pilot experiments** with slowed down beams (stable and near stable) @ **FRS Ion Catcher**, e.g. S532
HELIAC	**Precision experiments with stable beams** **LINAC Ion Catcher** new isotopes mass spectrometry nuclear spectroscopy
Super-FRS SIS100 & PSU	**LEB Ion Catcher & Upgraded "CORSET"** **new isotopes with secondary beams**

LOI U325: Dickel et al.
endorsed by GPAC (2020):

"This Letter of Intent (LoI) outlines the future directions to be taken in developing a program of study of multi-nucleon transfer (MNT) reactions at GSI, bringing interested parties together and developing the experimental and theory forces needed. This is ***very important in view of the future FAIR physics program*** with a focus on N=126 and super heavy nuclei, and possibly new neutron-rich beams delivered following separation of MNT reaction products. ***The committee supports this LoI.***"

Workshop Foto