

Plans and Challenges of NUSTAR



Sweden@FAIR

J. Gerl

for the NUSTAR collaboration

February 2, 2023

GSI Darmstadt



Fundamental questions to be answered by NUSTAR:

What are the limits for existence of nuclei?

Where are the proton and neutron drip lines situated?

Where does the nuclear chart end?

How does the nuclear force depend on varying proton-to-neutron ratios?

What is the isospin dependence of the spin-orbit force?

How does shell structure change far away from stability?

How to explain collective phenomena from individual motion?

What are the phases, relevant degrees of freedom, and symmetries of the nuclear many-body system?

How are complex nuclei built from their basic constituents?

What is the effective nucleon-nucleon interaction?

How does QCD constrain its parameters?

Which are the nuclei relevant for astrophysical processes and what are their properties?

What is the origin of the heavy elements?

How to get answers?

Study the properties and the behaviour of exotic nuclei!

Ground state
*mass, binding energy,
spin, parity...*

Excited states
*energy, spin, moments,
transition probability...*

Decay
lifetime, energy, modes...

Reaction
*kinetics, energy,
constituents...*

Investigate systematically many isotopes far off stability

NUSTAR - The Project



DESPEC	γ -, β -, α -, p-, n-decay spectroscopy
ELISE	elastic, inelastic, and quasi-free e ⁻ -A scattering
EXL	light-ion scattering reactions in inverse kinematics
HISPEC	in-beam γ spectroscopy at low and intermediate energy
ILIMA	masses and lifetimes of nuclei in ground and isomeric states
LASPEC	Laser spectroscopy
MATS	in-trap mass measurements and decay studies
R3B	kinematically complete reactions at high beam energy
Super FRS	RIB production, identification and spectroscopy
SHE	Nuclear physics and chemistry of super-heavy elements

The Approach

Complementary measurements leading to consistent answers

The Collaboration

> 850 scientists

184 institutes

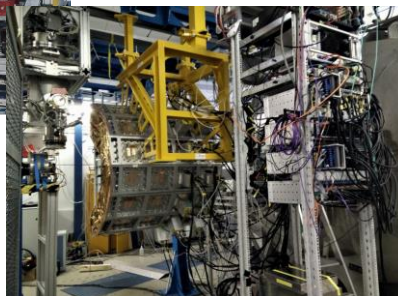
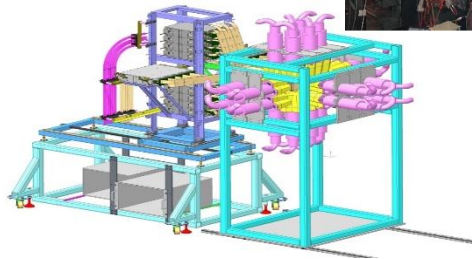
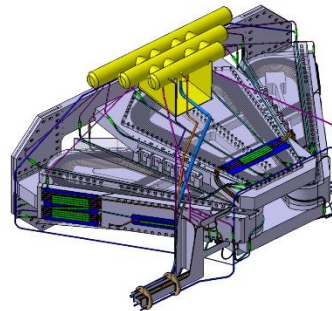
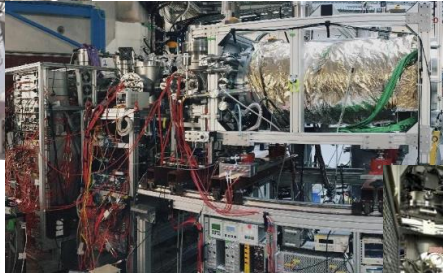
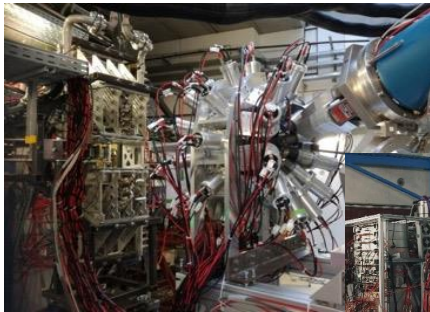
39 countries

NUSTAR - The Project



Evolutionary approach:

Advancing instrumentation by continuous development and gaining experience by physics exploitation



The Approach

Complementary measurements leading to consistent answers

The Collaboration

> 850 scientists

184 institutes

39 countries

>50 instrumentation sub-projects (MSV)

several 1000 major components

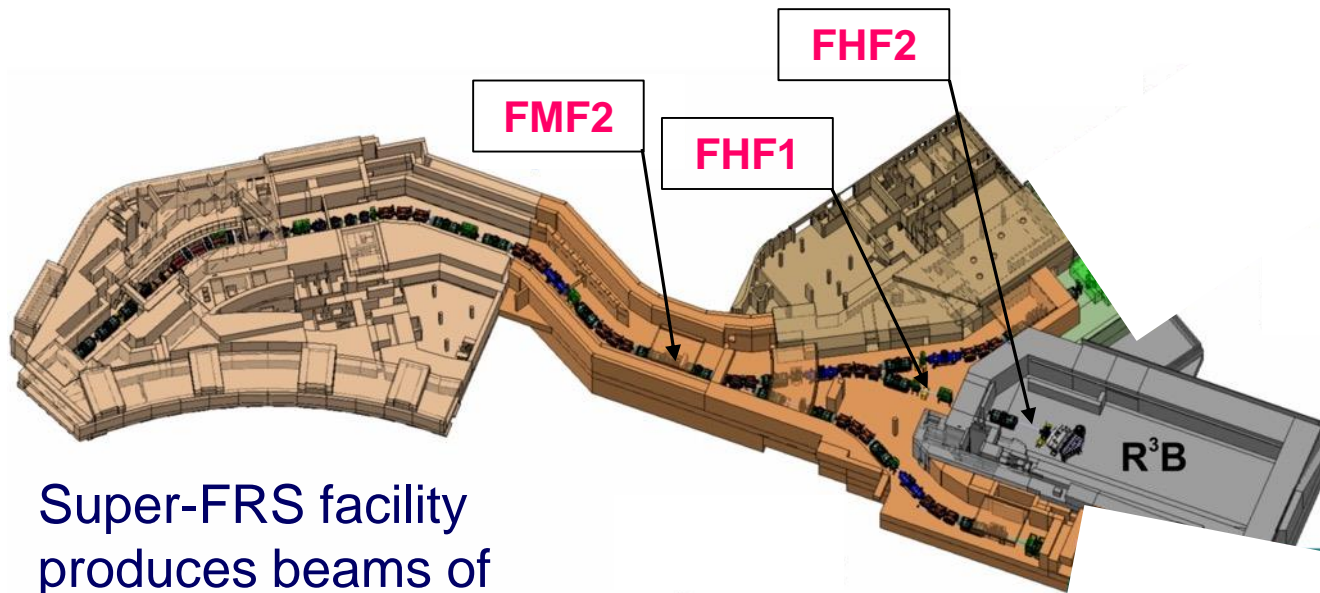
Sweden provides many valuable contributions to the NUSTAR instrumentation



Sub-system	Work package	PSP code	Contribution	Institute	Country	IK value (KEUR)	FAIR/ext	Status	Council	Phase	Stage
HISPEC/DESPEC	1.2.2.1 Beam tracking and identification	1.2.2.1.7	ToF start detector	Lund Univ.	Sweden		ext	secured		Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.2 HISPEC/DESPEC beam line	1.2.2.2.2	HISPEC/DESPEC Beamline (2nd share)	Lund Univ.	Sweden		ext	secured		Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.2 HISPEC/DESPEC beam line	1.2.2.2.3	HISPEC/DESPEC Beamline (3rd share)	Lund Univ.	Sweden		ext	Eol		Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.3 HISPEC/DESPEC Mechanics	1.2.2.3.5	Mechanics (rails, support, etc) + installation (5th share)	Lund Univ.	Sweden		ext	secured		Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.10 LYCCA	1.2.2.10.2	LYCCA (2nd share)	Lund Univ.	Sweden		FAIR	secured	XI.19.10	Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.10 LYCCA	1.2.2.10.4	LYCCA (4th share)	Lund Univ.	Sweden		ext	secured		Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.14.1 DEGAS stage 1	1.2.2.14.1.4	DEGAS stage 1 (4th share)	KTH Stockholm	Sweden		ext	secured		Exp Ph. 0	
HISPEC/DESPEC	1.2.2.14.2 DEGAS stage 2	1.2.2.14.2.4	DEGAS stage 2 (4th share)	KTH Stockholm	Sweden		ext	secured		Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.14.2 DEGAS stage 2	1.2.2.14.2.5	DEGAS stage 2 (5th share)	KTH Stockholm	Sweden		FAIR	secured	XX.13.5	Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.14.2 DEGAS stage 2	1.2.2.14.2.13	DEGAS stage 2 (13th share)	KTH Stockholm	Sweden		FAIR	secured	XXII.13.1	Exp Ph. 1a / Acc	
HISPEC/DESPEC	1.2.2.16.3 NEDA	1.2.2.16.3.1	NEDA (1st share)	Uppsala Univ.	Sweden		ext	secured		Exp Ph. 2	
HISPEC/DESPEC	1.2.2.16.3 NEDA	1.2.2.16.3.2	NEDA (2nd share)	Uppsala Univ.	Sweden		ext	secured		Exp Ph. 2	
R3B	1.2.5.1.1.3 infrastructure (magnets)	1.2.5.1.1.3.2	Flex line GLAD	VR-RFI	Sweden		ext	secured		Exp Ph. 1a / Acc	
R3B	1.2.5.1.2.3.1.1 CALIFA barrel stage 1	1.2.5.1.2.3.1.1.5	CALIFA barrel stage 1 (5th share)	Lund Univ.	Sweden		FAIR	secured	VIII.19.6	Exp Ph. 0	
R3B	1.2.5.1.2.3.2 CALIFA fwd endcap	1.2.5.1.2.3.2.1	CALIFA forward endcap (1st share)	Chalmers	Sweden		FAIR	secured	XX.13.6 - split	Exp Ph. 0	
R3B	1.2.5.1.2.3.2 CALIFA fwd endcap	1.2.5.1.2.3.2.3	CALIFA forward endcap (3rd share)	Chalmers	Sweden		ext	secured		Exp Ph. 0	
R3B	1.2.5.1.2.3.2 CALIFA fwd endcap	1.2.5.1.2.3.2.4	CALIFA forward endcap (4th share)	Chalmers	Sweden		FAIR	secured	XXII.13.2	Exp Ph. 0	
R3B	1.2.5.1.3 Vacuum systems	1.2.5.1.3.3	Vacuum systems (3rd share)	Lund Univ.	Sweden		ext	secured		Exp Ph. 1a / Acc	
R3B	1.2.5.1.4 DAQ	1.2.5.1.4.2	DAQ electronics (2nd share)	Chalmers	Sweden		ext	secured		Exp Ph. 0	
R3B	1.2.5.1.4 DAQ	1.2.5.1.4.4	DAQ electronics (4th share) - CALIFA	Lund Univ.	Sweden		ext	secured		Exp Ph. 0	
R3B	1.2.5.1.5 Infrastructure	1.2.5.1.5.2	Infrastructure CALIFA	Lund Univ.	Sweden		ext	secured		Exp Ph. 0	
R3B	1.2.5.1.5 Infrastructure	1.2.5.1.5.3	Media supply	Lund Univ.	Sweden		ext	secured		Exp Ph. 1a / Acc	
R3B	1.2.5.1.5 Infrastructure	1.2.5.1.5.4	Electronics infrastructure	Chalmers	Sweden		ext	secured		Exp Ph. 1a / Acc	
Total value (KEUR):						2827.9					

Replacement of aging components and upgrade

Early/First science Start-up at FAIR in 2027 with Super-FRS and High Energy Branch



Super-FRS facility
produces beams of
exotic nuclei
(talk by H. Simon)

NUSTAR Experiments will be performed
at **experimental areas** of the Super-FRS

Challenge: Rapid exchange of delicate detector set-ups with demanding infrastructure requirements

Needed infrastructure items for ES/FS

PSP-Code	Description	data from approved TDR
1.2.1.8	Media supplies	no
1.2.1.9	Safety	no
1.2.1.10	IT infrastructure	no
1.2.1.11	Mechanics and alignment	no
1.2.2.1.8	Scintillators in vacuum	yes
1.2.2.5	Safety	yes
1.2.5.1.1.3.3	GLAD feedbox	yes
1.2.5.1.1.3.4	GLAD warm piping	yes
1.2.5.1.1.3.5	GLAD infrastructure	no
1.2.5.1.3.4	Vacuum systems (4th share)	yes
1.2.5.1.5.1	Mechanics and alignment	yes
1.2.6.4.4	ToF detectors - infrastructure CR	yes
1.2.6.6.4	DAQ - common infrastructure	yes
1.2.10.1.1.2	DAQ infrastructure (share 2)	yes
1.2.10.1.2.1.1	Pendulum valves (share 1)	yes
1.2.10.1.2.3	60L dewar	yes
1.2.10.1.2.4	LN2 piping	yes
		Total

New: Several movable platforms are needed for ES/FS

Needed infrastructure items for ES/FS

PSP-Code	Description	data from approved TDR
1.2.1.8	Media supplies	no
1.2.1.9	Safety	no
1.2.1.10	IT infrastructure	no
1.2.1.11	Mechanics and alignment	no
1.2.2.1.8	Scintillators in vacuum	yes
1.2.2.5	Safety	yes
1.2.5.1.1.3.3	GLAD feedbox	yes
1.2.5.1.1.3.4	GLAD warm piping	yes
1.2.5.1.1.3.5	GLAD infrastructure	no
1.2.5.1.3.4	Vacuum systems (4th share)	yes
1.2.5.1.5.1	Mechanics and alignment	yes
1.2.6.4.4	ToF detectors - infrastructure CR	yes
1.2.6.6.4	DAQ - common infrastructure	yes
1.2.10.1.1.2	DAQ infrastructure (share 2)	yes
1.2.10.1.2.1.1	Pendulum valves (share 1)	yes
1.2.10.1.2.3	60L dewar	yes
1.2.10.1.2.4	LN2 piping	yes
		Total

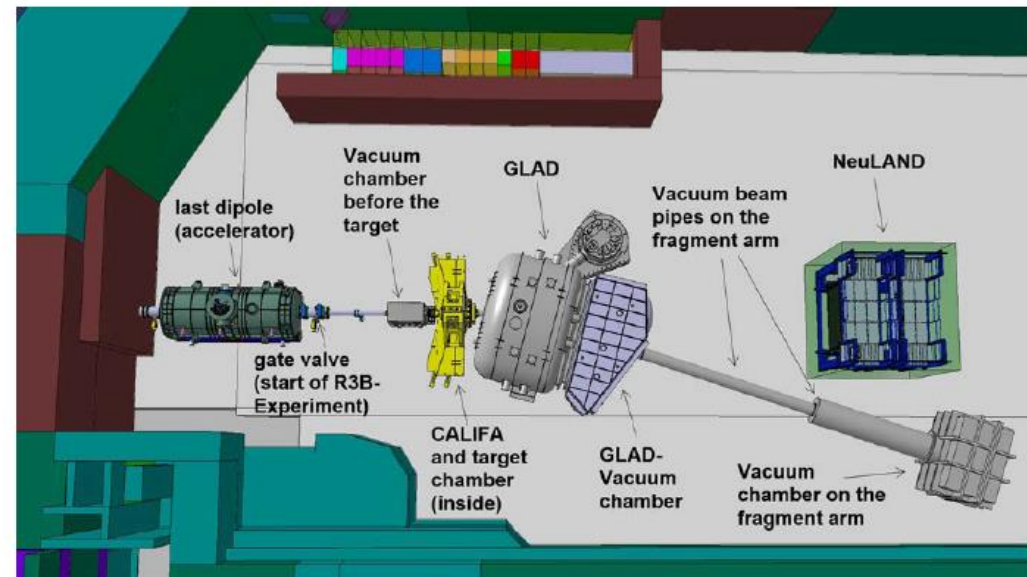
New: Several movable platforms are needed for ES/FS

Vacuum systems (example)

PSP-Code	Description	data from approved TDR
1.2.5.1.3.4	Vacuum systems (4th share)	yes

PSP code	description	cost (2005)	component
1.2.5.1.3.4	Vacuum systems (4th share)	114.9	multiple items
			ToF chamber
			section 1 - pre-pump
			section 3 - pre-pump
			large beam pipe

ToF chamber will be co-financed with GSI project funds



Needed infrastructure items for ES/FS

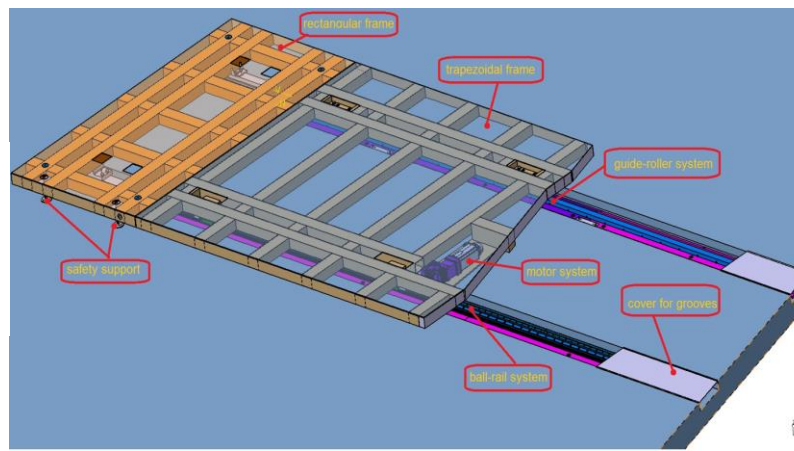
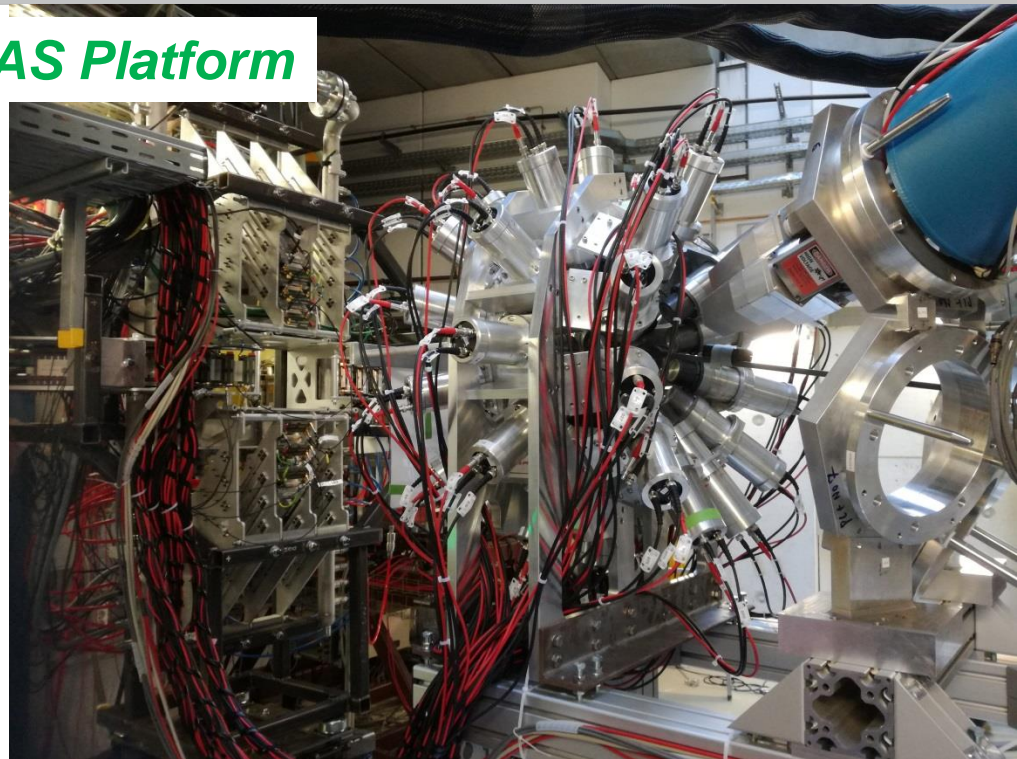
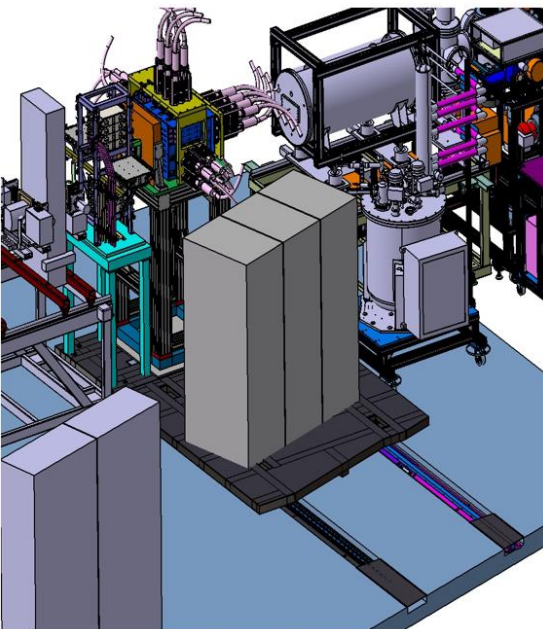
PSP-Code	Description	data from approved TDR
1.2.1.8	Media supplies	no
1.2.1.9	Safety	no
1.2.1.10	IT infrastructure	no
1.2.1.11	Mechanics and alignment	no
1.2.2.1.8	Scintillators in vacuum	yes
1.2.2.5	Safety	yes
1.2.5.1.1.3.3	GLAD feedbox	yes
1.2.5.1.1.3.4	GLAD warm piping	yes
1.2.5.1.1.3.5	GLAD infrastructure	no
1.2.5.1.3.4	Vacuum systems (4th share)	yes
1.2.5.1.5.1	Mechanics and alignment	yes
1.2.6.4.4	ToF detectors - infrastructure CR	yes
1.2.6.6.4	DAQ - common infrastructure	yes
1.2.10.1.1.2	DAQ infrastructure (share 2)	yes
1.2.10.1.2.1.1	Pendulum valves (share 1)	yes
1.2.10.1.2.3	60L dewar	yes
1.2.10.1.2.4	LN2 piping	yes
		Total

New: Several movable platforms are needed for ES/FS

ES/FS requires special Experiment Platforms



Example of AIDA+FATIMA+DEGAS Platform



Sub-millimeter accuracy for precise positioning of detection systems...

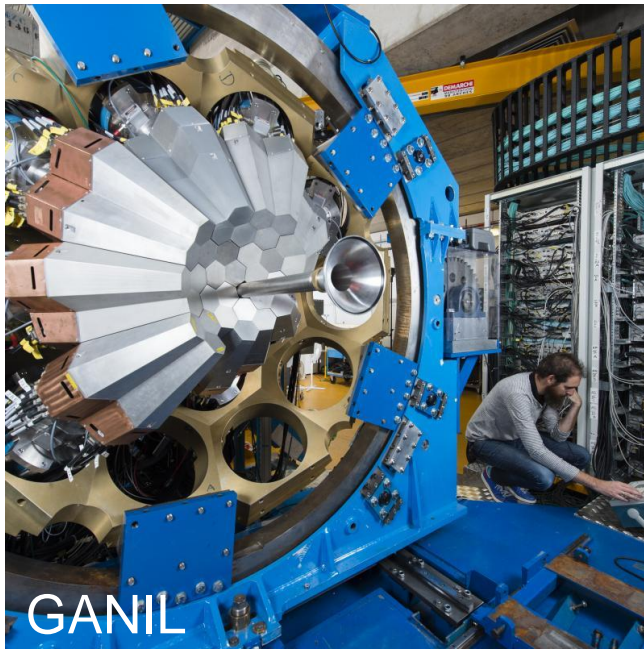
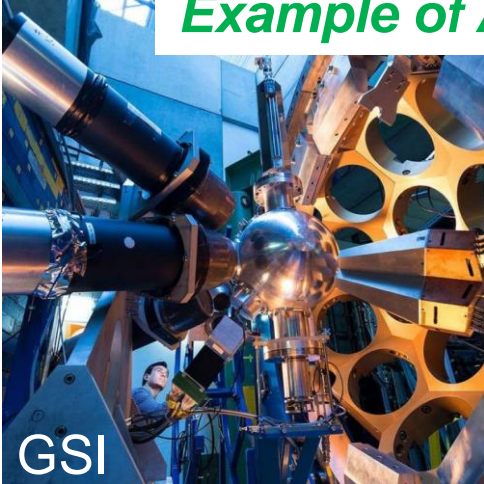
Ultrasoft acceleration and deceleration for shock-free movement...

Precise 2D on floor movement...

ES/FS requires special Experiment Platforms



Example of AGATA Platform



Compact high-
precision rotatable
honeycomb frame...

sub-mm distortions at
detector heads...

NUSTAR JG

Conclusions



- NUSTAR at GSI/FAIR enables unique and important contributions to our understanding of the atomic nucleus
- Planned and available instrumentation is state-of-the-art
- Quite some infrastructure items are required to operate a multitude of detector systems
- Sophisticated platforms with sub-mm mechanical precision are needed to enable rapid exchange of set-ups
- **Help with infrastructure and platforms is highly welcome**