DESPEC

Decay Spectroscopy post SFRS @ NUSTAR, FAIR.

Cath Scholey, Mini-FAIR workshop,
JYFL, 26th November 2015.

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

NUclear STructure Astrophysics and Reactions

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?

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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 invere 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

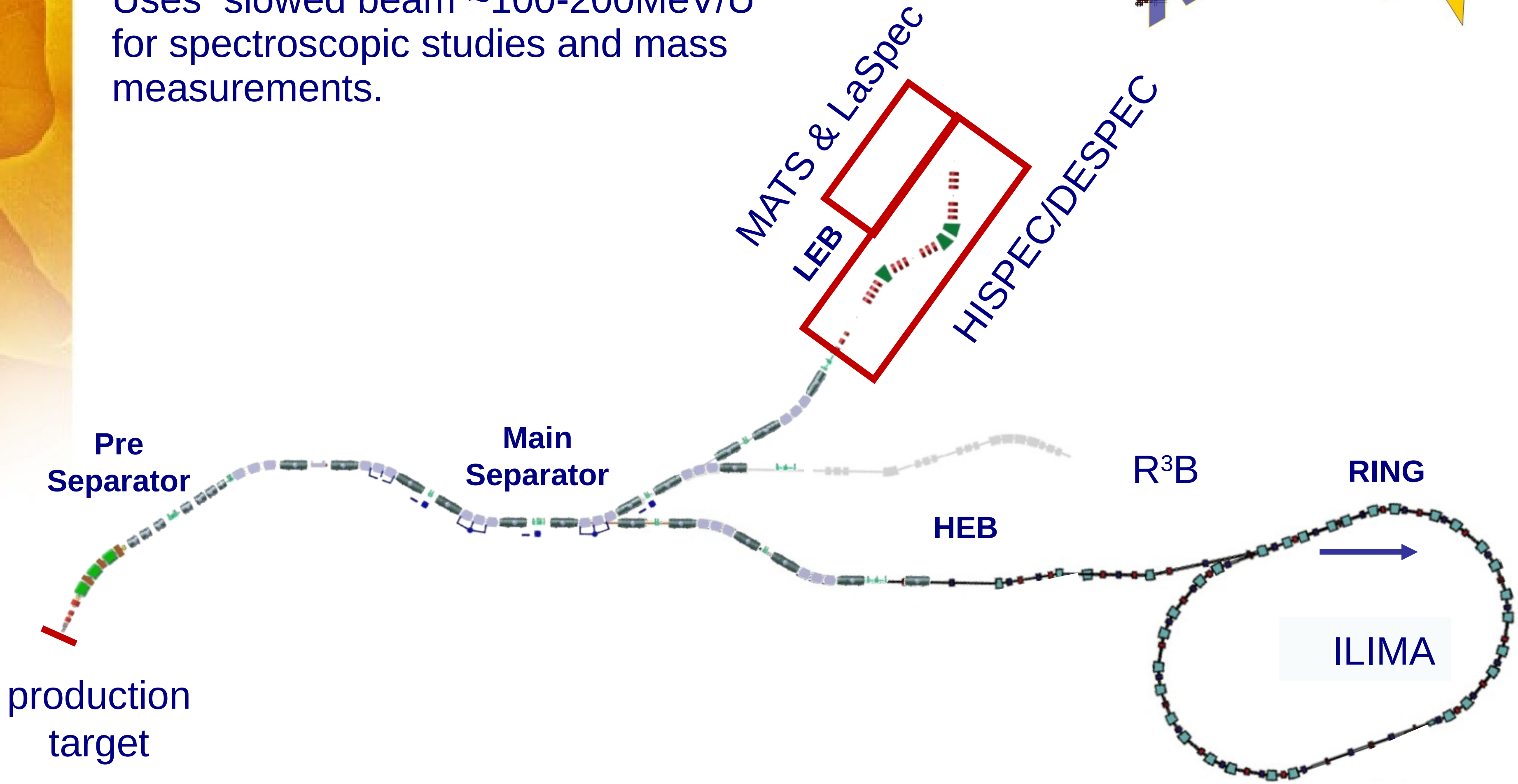
184 institutes

39 countries

NUSTAR - The Facility

Low **E**nergy **B**ranch:HISPEC, DESPEC, MATS, LASPEC

Uses slowed beam ~100-200MeV/U for spectroscopic studies and mass measurements.



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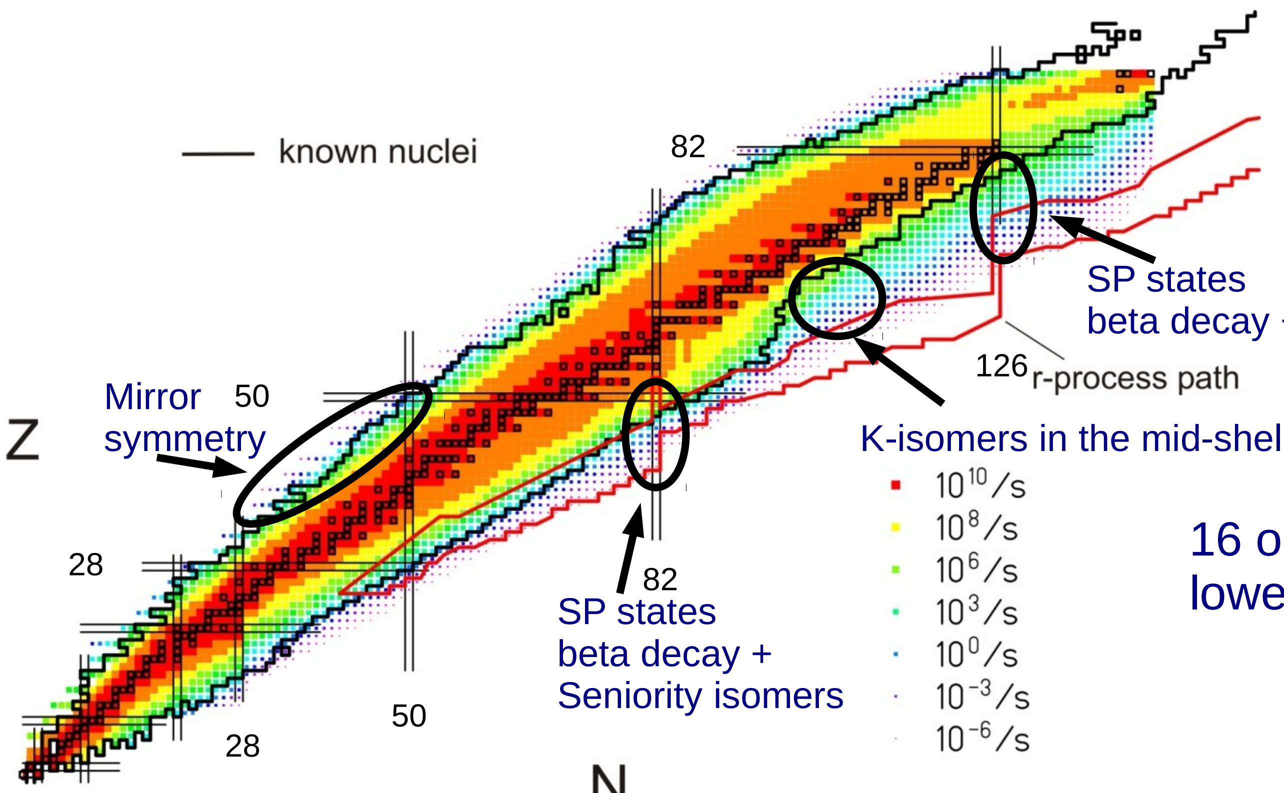
What is DESPEC?

- Suite of detectors for Isomeric and ground state decay studies of nuclei over the nuclear chart.
- Next generation after the Rising Stopped beam campaign @ GSI and the now running EURICA @ RIKEN and BRIKEN campaigns.
- Uses stopped beam.
- Central component is the implantation detector (AIDA) – Also detects alpha decays, electrons/positrons (beta decay or conversion electrons) and protons emission.
- Other detectors required for Gamma rays and Neutrons: DEGAS, FATIMA, DTAS, Monster and BELEN.
- This talk will concentrate on DEGAS and AIDA.

Aims and possibilities:

Stop the Ions (worst case A=200, Energy 200MeV/U ~ 40GeV ions!)
Identify (new) isotopes: Firstly, by Z, A/Q.
After identification: measure their decays: alpha (3-10MeV), protons (0.5-2MeV), beta decay (>0 – 10MeV), X-rays and Gamma rays (>0 – 10MeV).

Issues: High implantation energies, rates, background, noise thresholds and timing



Fragmentation beams access regions stable beams can not: Fast ID of exotic ions

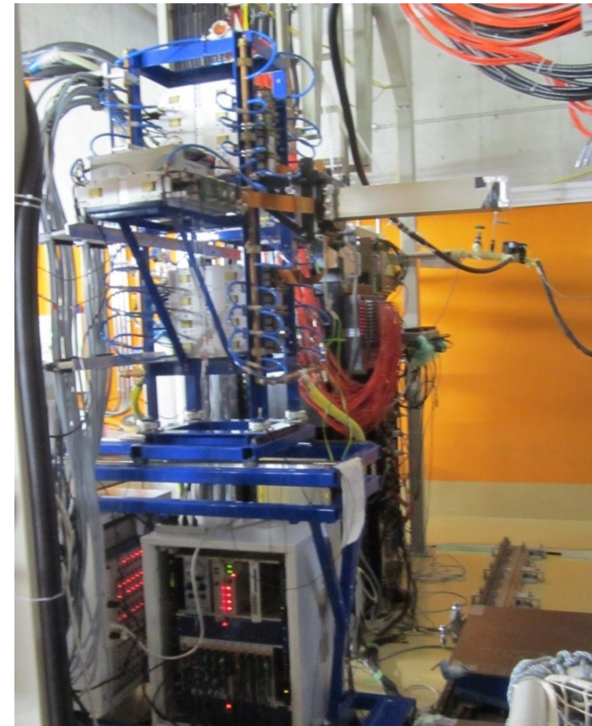
16 orders of magnitude!
lower limit ~pbarns

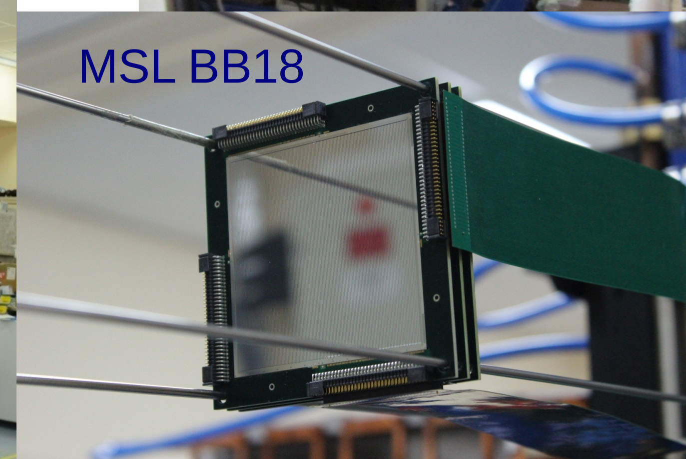
AIDA: Advanced Implantation Detector Array

UK-funded project:
STFC Daresbury, RAL and Edinburgh, Liverpool Universities

Detector: multi-plane Si DSSD array
wafer thickness 1mm
8cm x 8cm (128x128 strips) *or* 24cm x 8cm (384x128 strips)

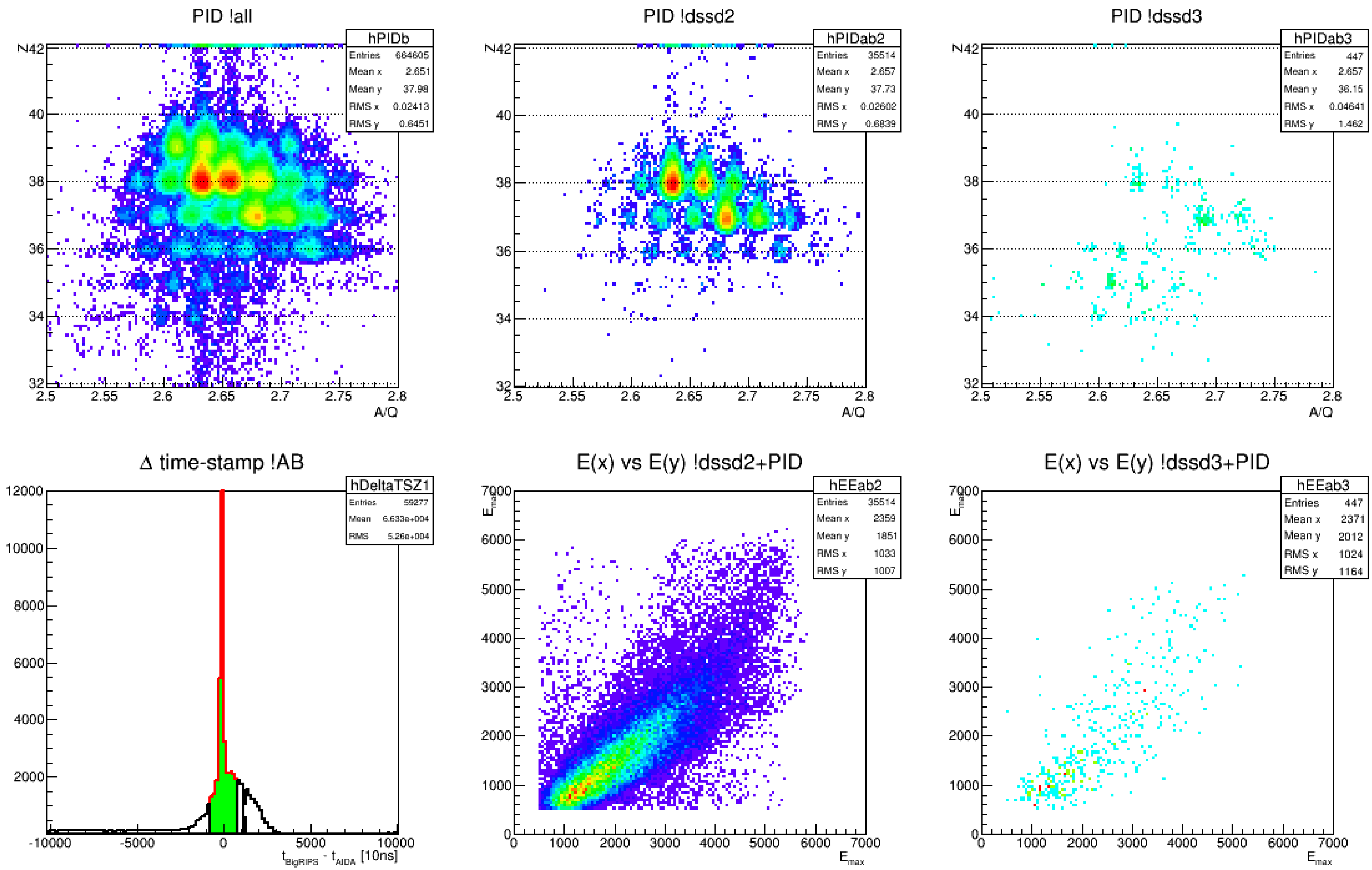
Instrumentation Specification: ASIC
low noise (<12keV FWHM), low threshold (0.25% FSR)
20GeV FSR *plus* (20MeV FSR *or* 1GeV FSR)
fast overload recovery (~µs)
spectroscopy performance
time-stamping & independent DAQ instances





Test setup at STFC Daresbury Lab:instrumentation for 32 FEE cards = 8 DSSD with 128x128 strips

AIDA: ^{100}Kr settings at RIKEN.



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AIDA + Ge

SFRS large image size: (3 x 8 =24cm) detectors 7 deep
Large area Ge coverage required.

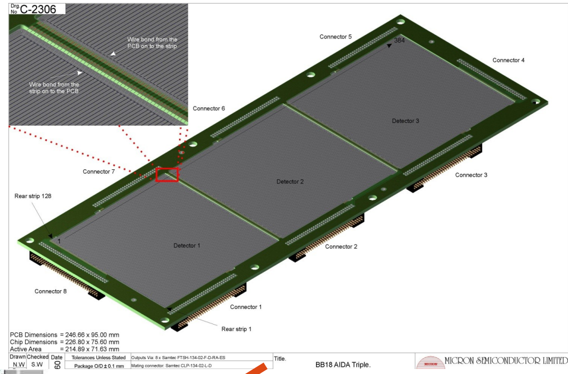
Implantation of the already tracked ion
gives timing reference.

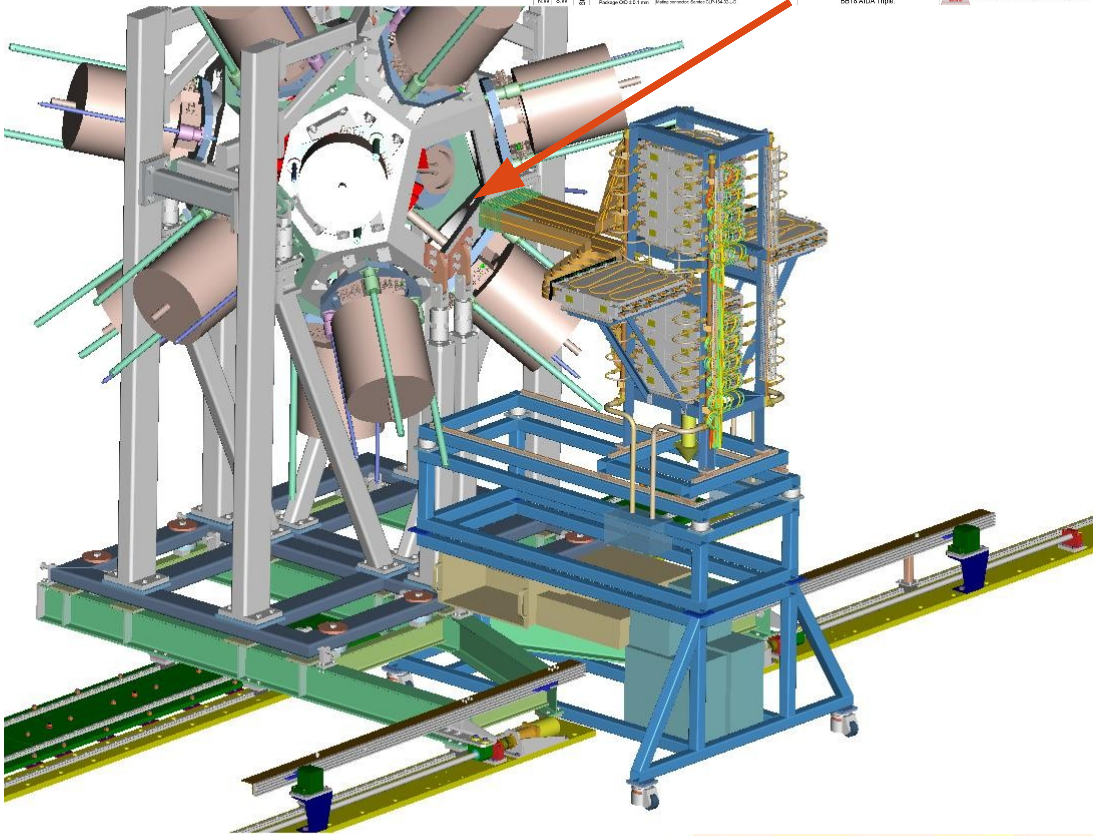
Isomer studies:
Implant - γ time + $\gamma - \gamma$ time

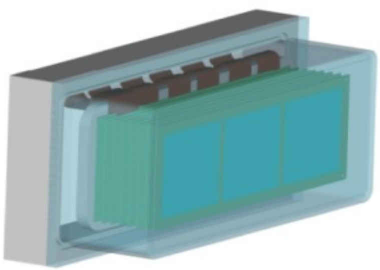
Isomer 1/2t (implant – γ time) level scheme (γ – γ time)

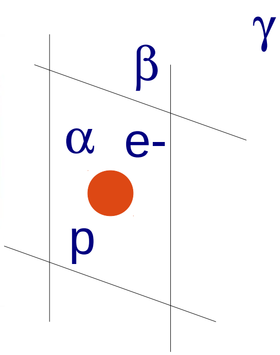
Decay studies:
Implant – decay correlation
Decay - γ time + $\gamma\gamma$ time

All effected by implantation rate.





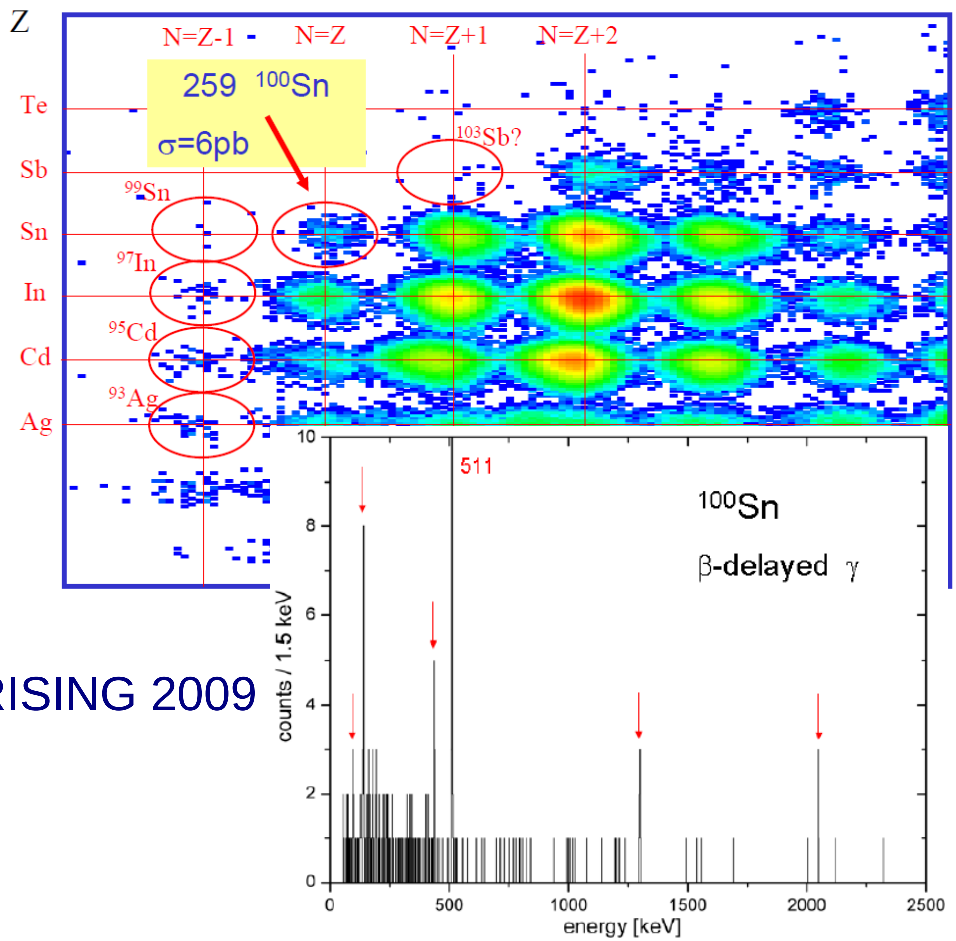




DEGAS: Physics requirements and constraints

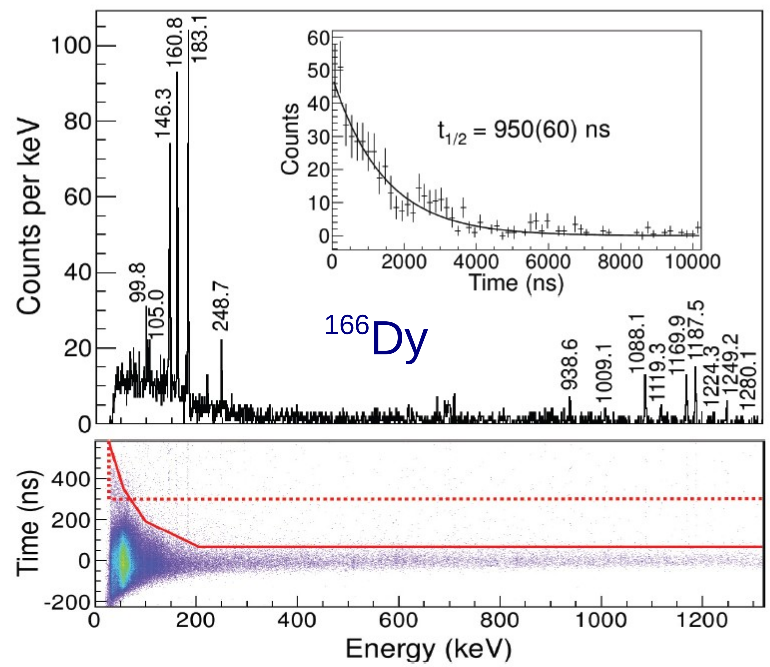
Only need a small number of events, but they must be clean.
Need low background environment.
Fragmentation beams cause background......known as the flash (up to 30 fold events above 10keV).
To minimise the blinding of the detectors high segmentation is required.

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



RISING 2009

Previously used 15 EUROBALL 7-fold cluster detectors = 105 Ge elements:
RISING: 2002-2009



Z. Patel et. al. Phys. Rev. Lett. **113,** 262502 (2014)

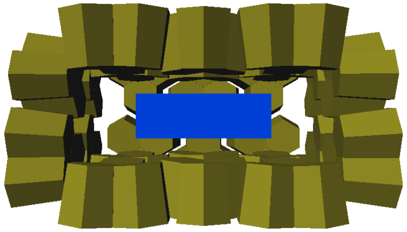
RIKEN

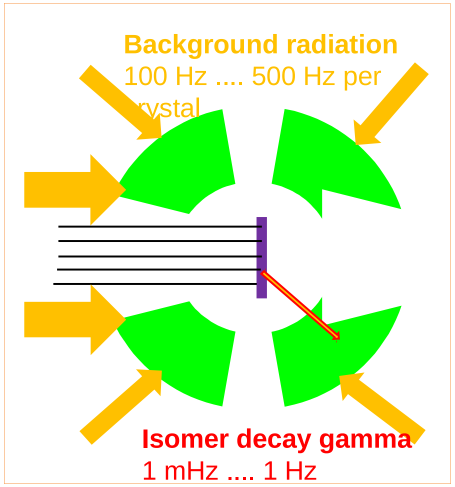
DEGAS:

Aim: To improve segmentation, efficiency and P/T (background suppression or tracking).

Modular solution working towards the optimal array.

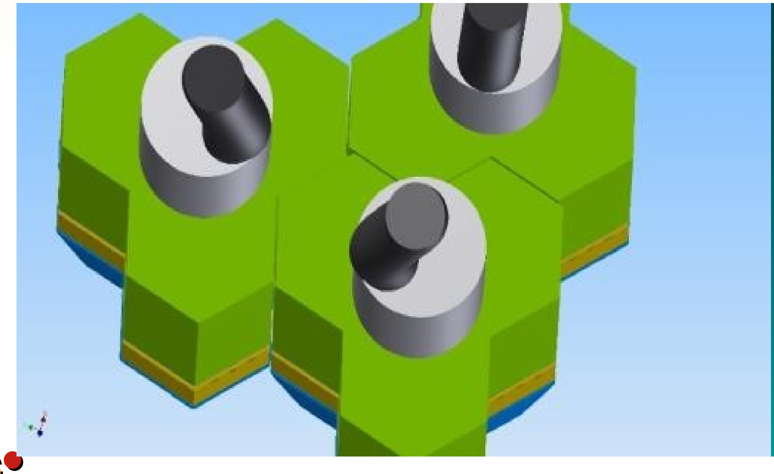
Phase I:
Make the geometry more compact.
Change 7-fold cluster to 3-fold
Change LN2 cooling to electrical
Add BGO backcatcher plus side shielding.

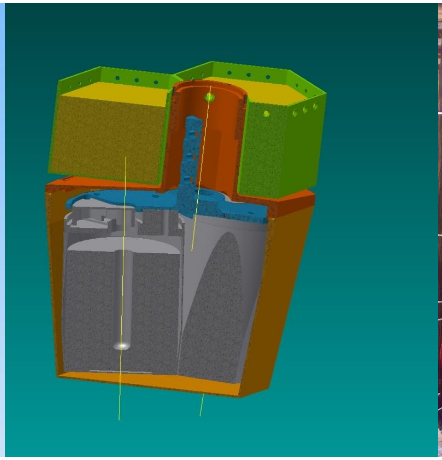


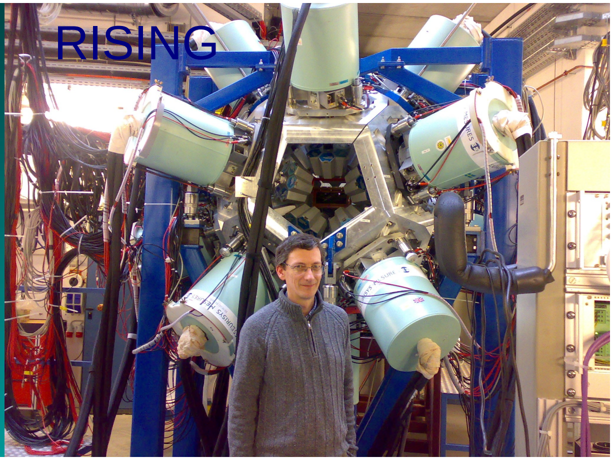


Phase II: 20 EUROBALL clusters in a circular configuration + 5 AGATA triple clusters at 0 degrees. Higher segmentation + tracking.

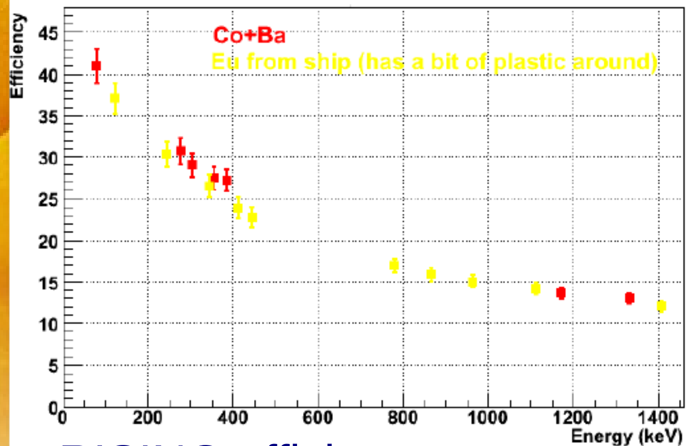
Phase III: Not in the DEGAS TDR, build a segmented stacked Ge planar array!



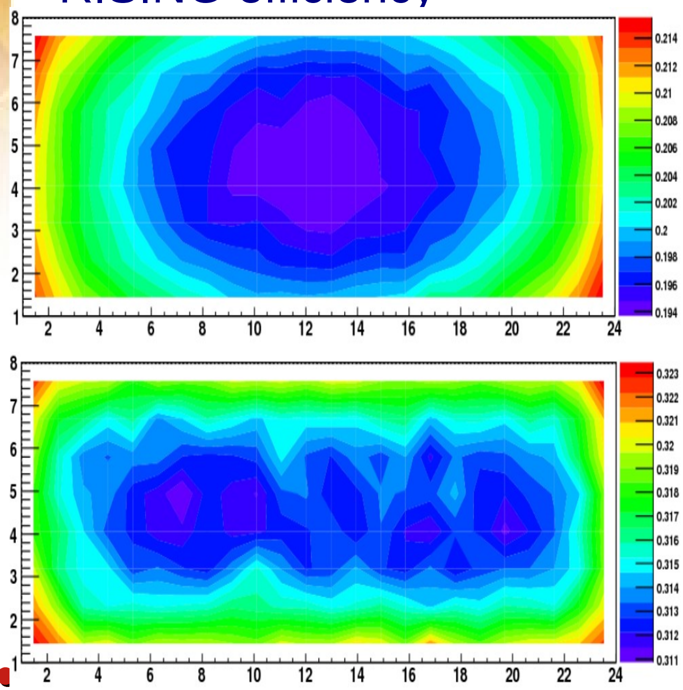




DEGAS



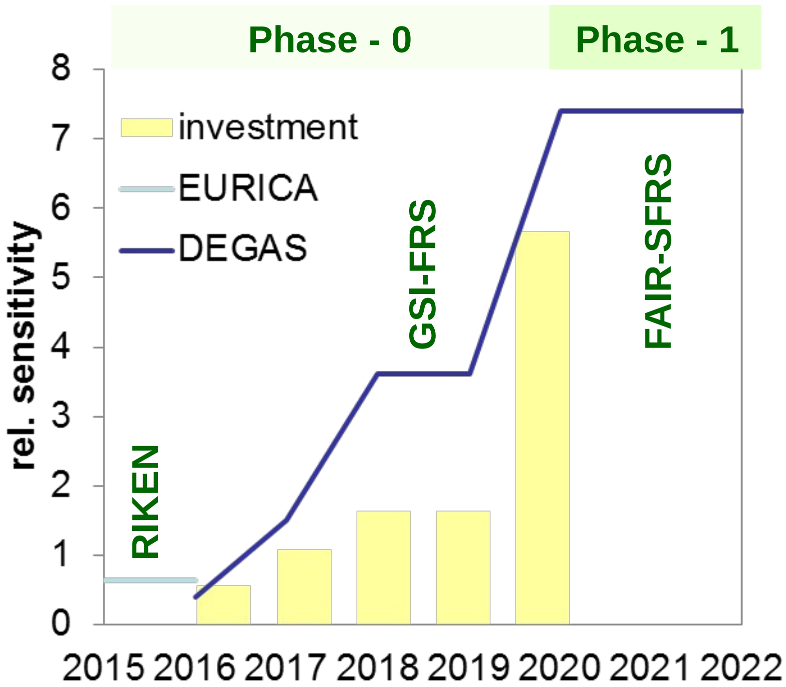
RISING efficiency



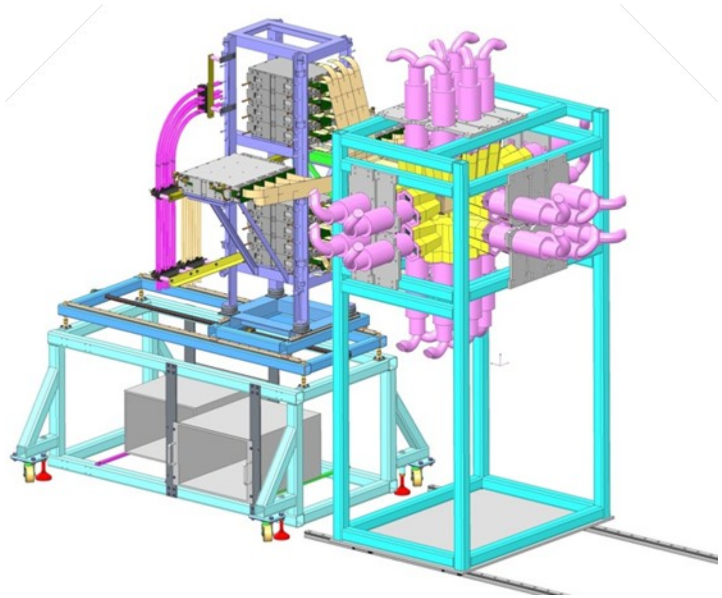
DEGAS efficiency and P/T

Property	RISING	Phase I	Phase II	Phase III
Array type	Composite Ge detector array	Composite Ge detector array	Phase I complem. by γ-tracking dets.	γ-imaging array
Energy range (keV)	50-5000	50-5000	50-5000	50-5000
Noise threshold (keV)	24	15	15	10
Energy resolution (at 1.3 MeV)	2.3 keV	2.3 keV	2.3 keV	2.0 keV
Full energy γ-detection efficiency (at 1 MeV)	16%	16%	18%	>20%
Effective full energy efficiency after prompt flash blinding	13.9%	14%	16%	20%
P/T-value	34%	34%	40%	>50%
Time resolution (at 1.3 MeV)	13 ns	10 ns	10 ns	< 10 ns
Overload recovery time	≤ 1ms	100 ns/MeV	100 ns/MeV	100 ns/MeV
Relative background suppression	1	5	10	100
Coverable implantation area	16 x 8 cm^2	24 x 8 cm^2	24 x 8 cm^2	24 x 8 cm^2
Max. acceptable event rate (kHz)	3.5	10	10	10

Work packages and funding: DEGAS array



DEGAS array



- The predecessor of DEGAS, namely EURICA is running currently in RIKEN.
- An intermediate version is planned for experiments at GSI from 2018 onwards.
- The full version shall be available once FAIR is operational.
- The course of construction is mainly determined by the availability of funding.

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Contribution and Plans

Finnish In-kind contribution purchases:
Phase I: Shielding detectors, BGO and Si-PM array Passive Pb shielding
Phase II: A single AGATA crystal, plus all electronics to readout the signals

Current beamtime planning:

Break for SIS-18 upgrade and UNILAC renovation.
Q3-4: UNILAC operation

Break for SIS-18 upgrade and UNILAC renovation, Operation of UNILAC (experiments) and SIS (tests) for 12 respectively 7 weeks

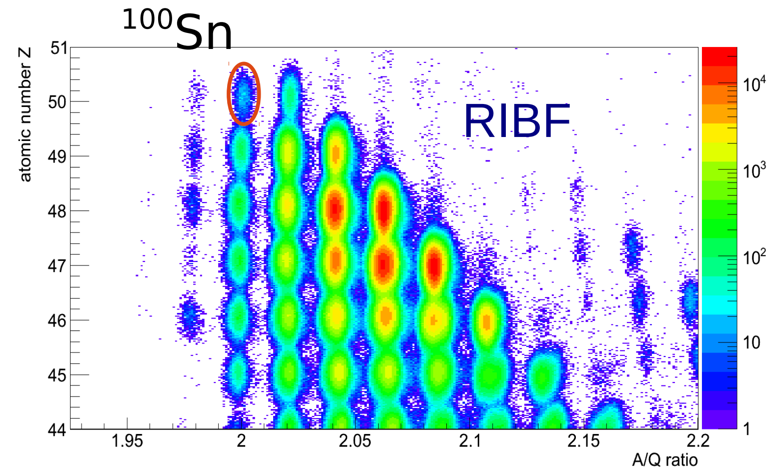
2017: Break for SIS-18 upgrade and shielding enforcement
Q3-4: SIS-18 commissioning

2018: 4-5 months, FAIR preparations and experiment programme

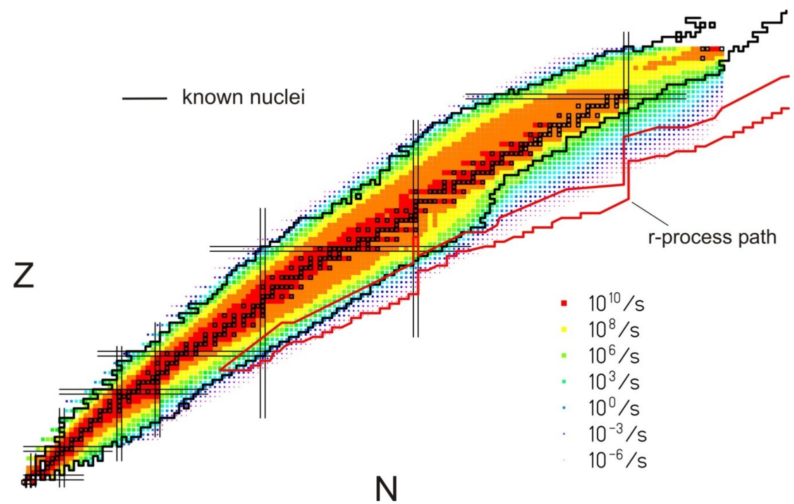
2019: 5-6 months, FAIR preparations and experiment programme

2020: 5-6 months, FAIR preparations and experiment programme

Physics for the Future is built on the past and present



2317 ^{100}Sn ions identified in BigRIPS, 1963 implanted in WAS3ABI



Niche: Fast separation ~200ns

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THE END

Thanks for listening