Opportunities for PARIS at HISPEC/DESPEC@FAIR

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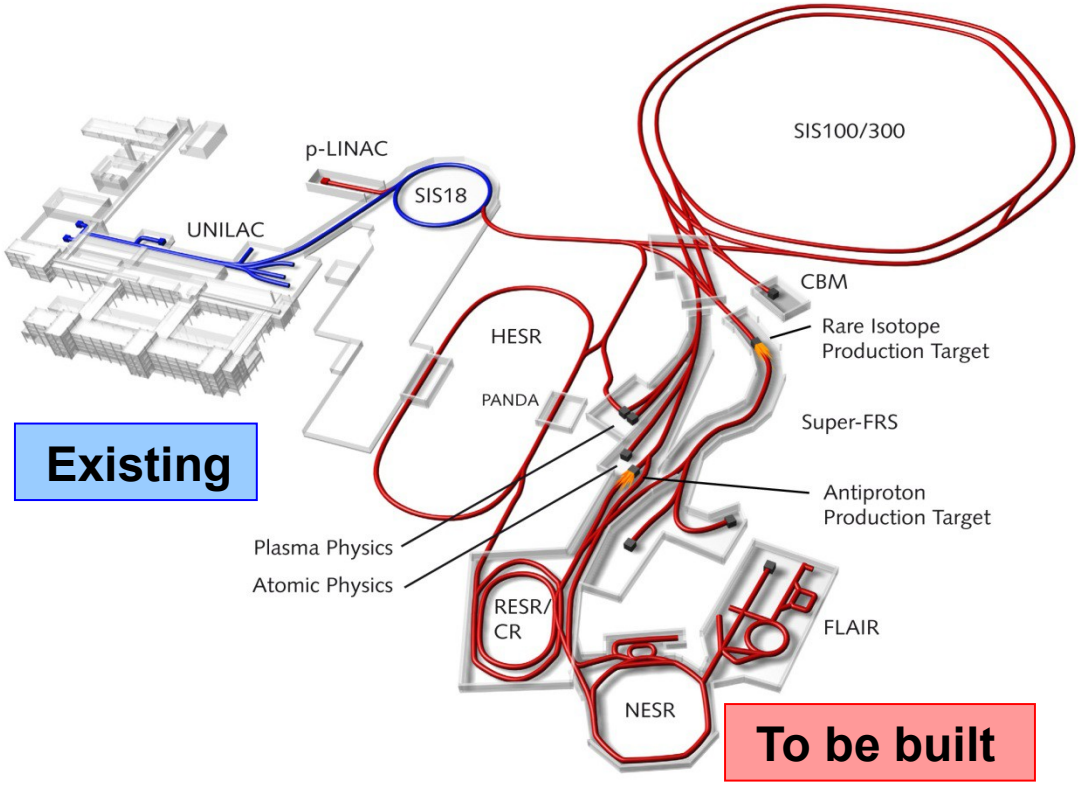
PARIS Collaboration Meeting

26.01.2018 – Warsaw, Poland

Facility for Antiproton and Ion Research



Existing

To be built

Primary Beams

- 10^{12}/s; 1.5-2 GeV/u; $^{238}U^{28+}$
- Factor 100-1000 over present in intensity
- 2(4)x10^{13}/s 30 GeV protons
- 10^{10}/s $^{238}U^{73+}$ up to 25 (- 35) GeV/u

Secondary Beams

- Broad range of radioactive beams up to 1.5 - 2 GeV/u; up to factor 10 000 in intensity over present
- Antiprotons 3 - 30 GeV

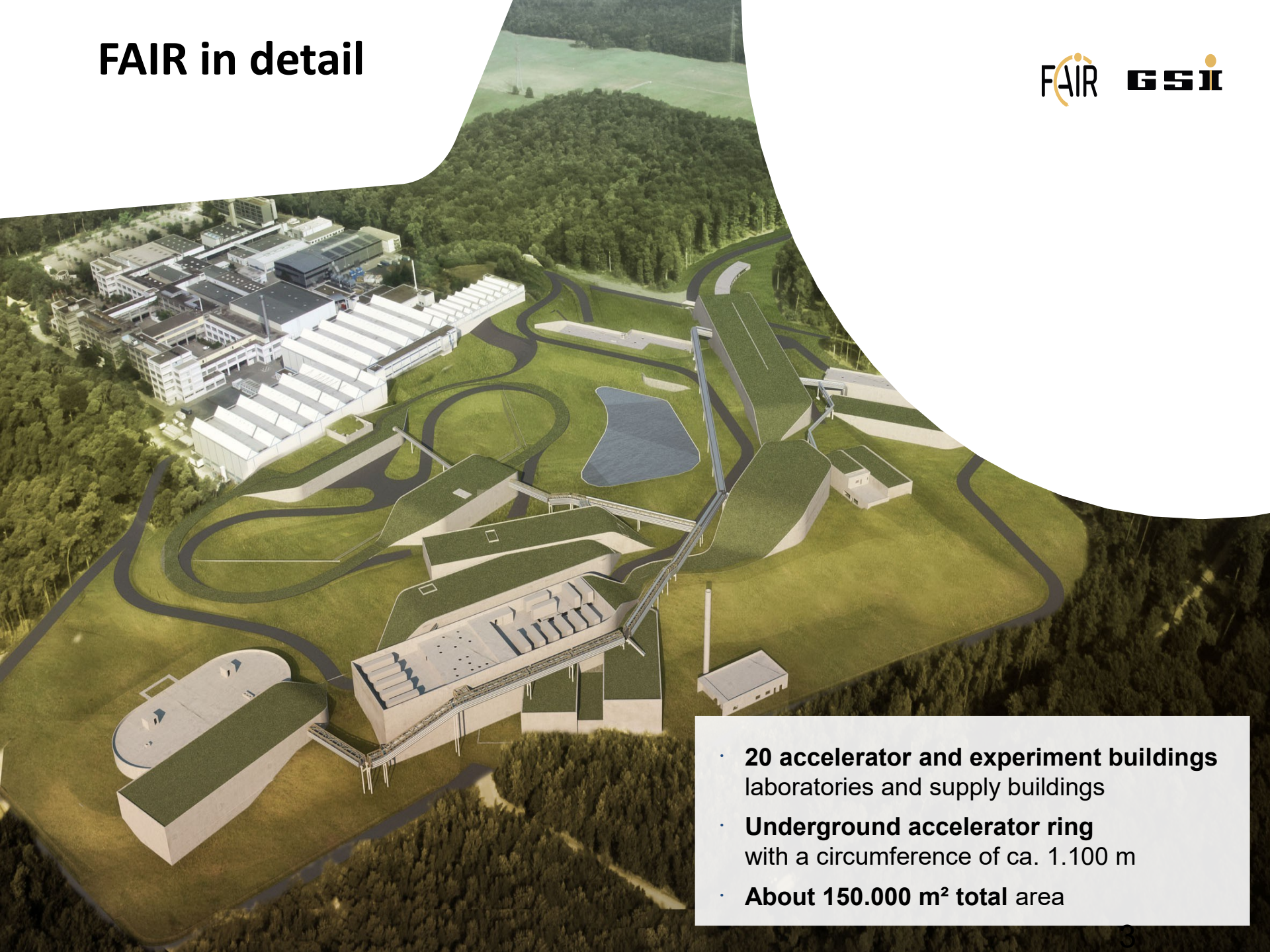
Storage and Cooler Rings

- Radioactive beams
- e – A collider
- 10^{11} stored and cooled 0.8 - 14.5 GeV antiprotons

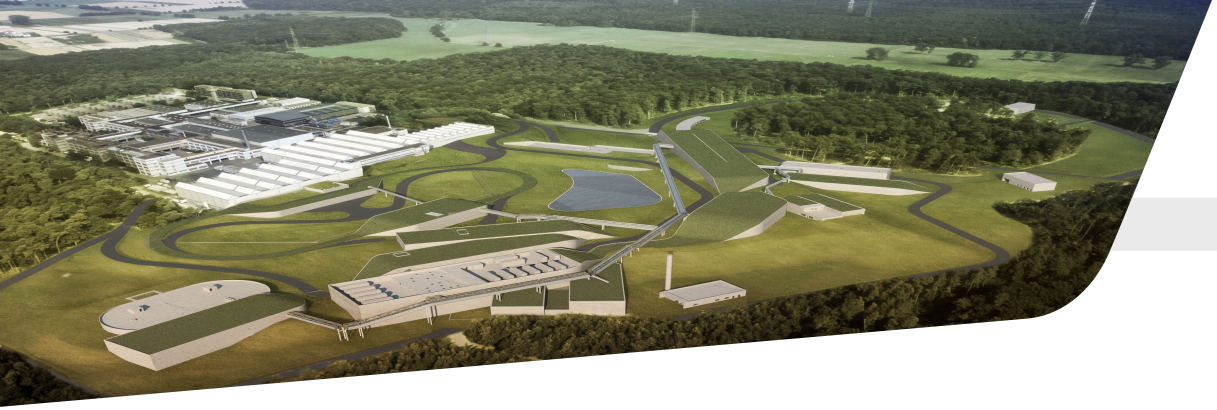
Key Technical Features

- Cooled beams
- Rapidly cycling superconducting magnets

FAIR in detail



- **20 accelerator and experiment buildings** laboratories and supply buildings
- **Underground accelerator ring** with a circumference of ca. 1.100 m
- **About 150.000 m² total** area



The Construction Project in Numbers

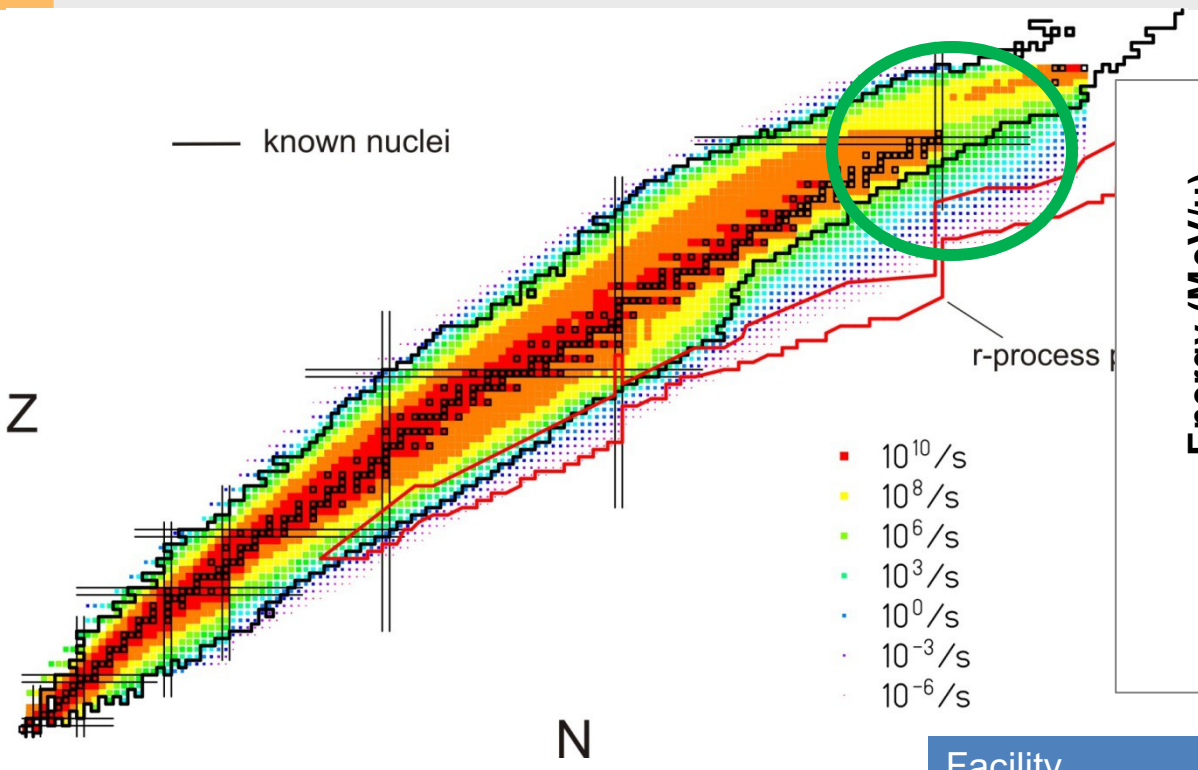
- Construction area 686.373 m² = 96 soccer fields
- Total floor space 158.661 m² = mid size airport
- 1.327 Ground piles 60.000 m
- Excavated earth 1.200.200 m3
- Concrete 625.000 m3 = weight of 5.000 family homes
- Iron 60.000 tons = weight of 9 Eiffel towers

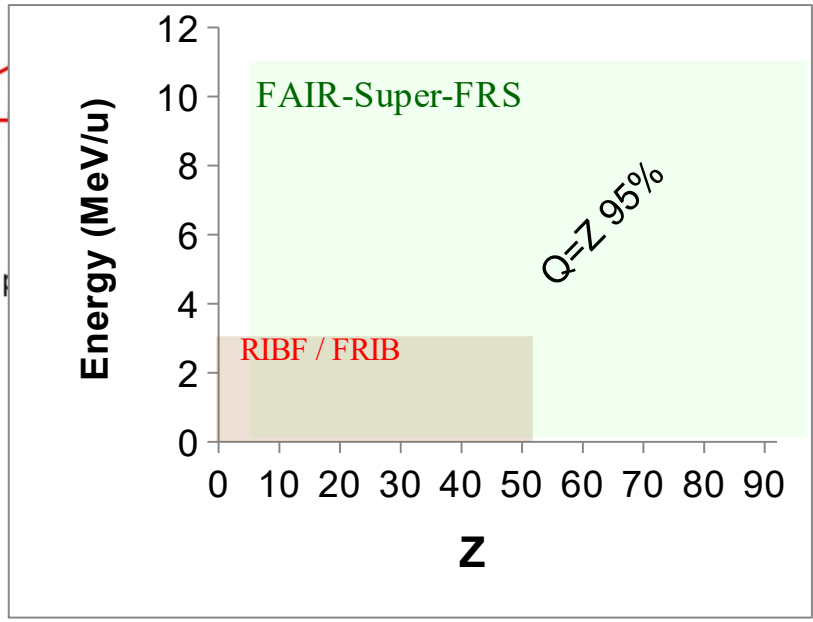
Achievements in construction since 2015

- Comprehensive civil construction plan:
  - completion of all buildings by 2022
- Full integrated planning for construction and commissioning of the entire project:
  - completion and commissioning of the full FAIR facility by 2025.
- Work is going on ...
  ... Groundbreaking for large SIS100 Synchrotron tunnel July 4th 2017 !

In time, below budget!

Uniqueness and Competitiveness





- High energies for unique separation and unique experiments
- Competitive intensities throughout the periodic table

Facility	U beam int. per spill at production target
previously at GSI	1...2x109
after the SIS18 upgrade at GSI	8x109
commissioning phase SIS100	2x1010
final full intensity with SIS100	3x1011

Experimental opportunities for high-resolution spectroscopy at FAIR/NUSTAR

Research field	Experimental method (beam-energy range)	Physics goals and observables	Beam int. (particle/s)
Nuclear structure, reactions and astrophysics	Intermediate energy Coulomb excitation, In-beam spectroscopy of fragmentation products (E/A ~ 100 MeV)	Medium spin structure, Evolution of shell structure and nuclear shapes, transition probabilities, moments,	101...105
	Multiple Coulomb excitation, direct and deep-inelastic, fusion evaporation reactions (E/A ~ 5 MeV; Coulomb barrier)	high spin structure, single particle structure, dynamical properties, transition probabilities, moments,	104...107
	Decay spectroscopy (E/A = 0 MeV)	half-lives, spins, nuclear moments, GT strength, isomer decay, beta-decay, beta-delayed neutron emission, exotic decays such as two proton, two neutron.	10-5...103

Extracted from HISPEC/DESPEC Technical Proposal , 12.2005

Planned instrumentation

HISPEC

-LYCCA *heavy ion calorimeter with ToF capability in operation*

-AGATA *gamma spectrometer in operation*

-Hyde *light particle array prototype*

-NEDA *Neutron detector array prototype*

-EDAQ *dedicated electronics and DAQ based on several branches*

DESPEC

-AIDA *active implantation device in operation*

-MONSTER *neutron ToF array under construction*

-BELEN *neutron detecion array in operation*

-DTAS *Decay Total Absorption Spectrometer in operation*

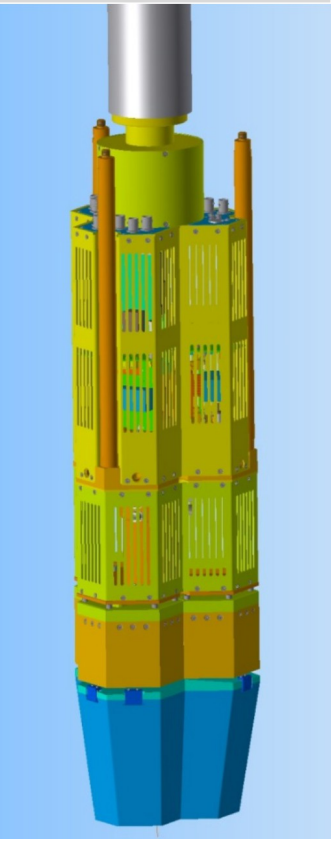
-DEGAS Ge Array *gamma spectrometer under construction*

-FATIMA *Fast timing array in operation*

-EDAQ *dedicated electronics and DAQ based on several branches*

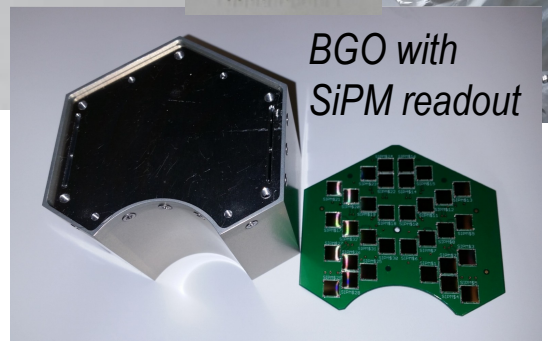
DESPEC: DEGAS Detector

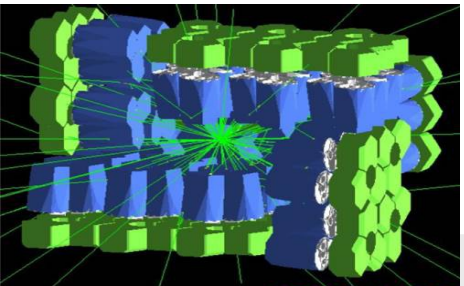
DEGAS γ-detector



A very complex and complicated device

- Encapsulated HPGe crystals in a cryostat with electrical cooling.
- Minimal thermal losses
- High vacuum
- Integrated front-end and control electronics
- Imaging capability
- ...



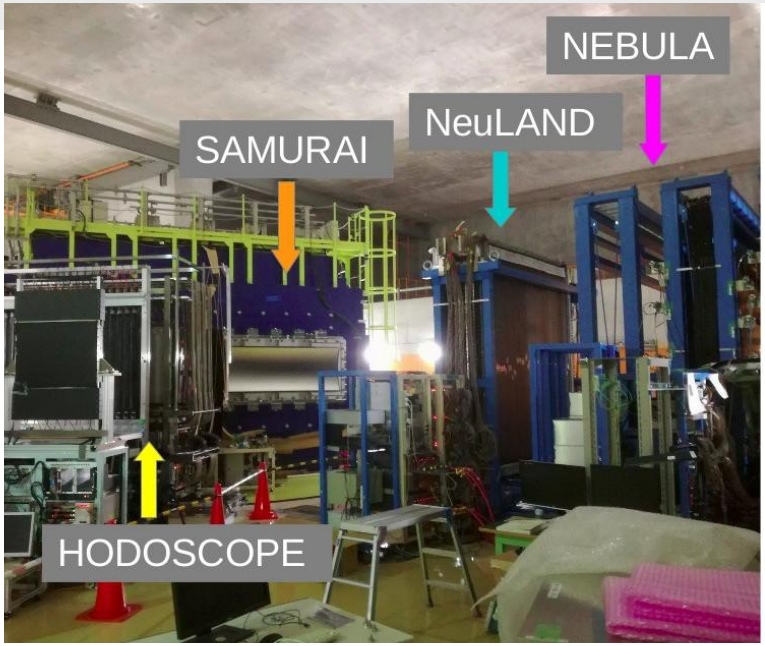


GSI - Germany
TIFR – India
ITÜ - Turkey

Assembly of pre-series started

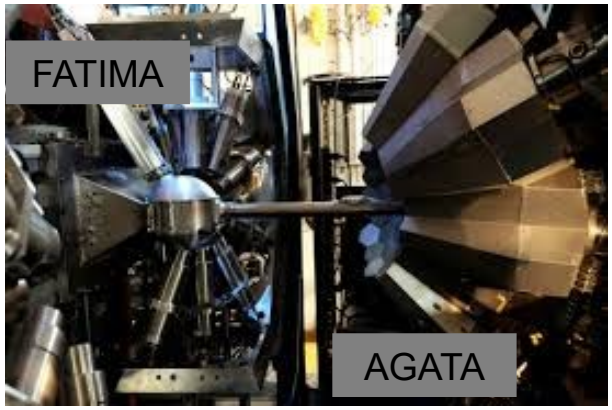
DEGAS Array in time for first Phase-0 experiments in 2019

Phase-0 detectors successfully used

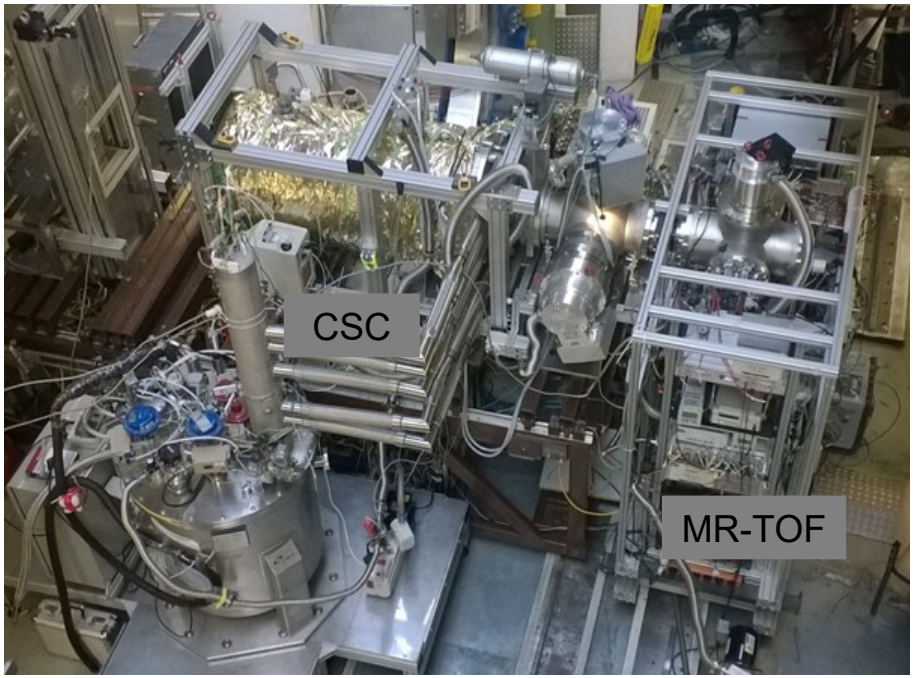


NEULAND in operation at RIKEN

DTAS in operation at JYFL

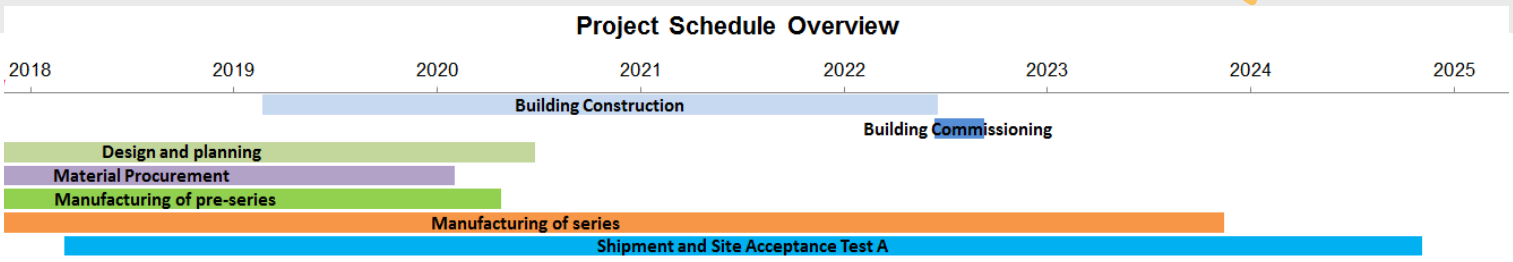


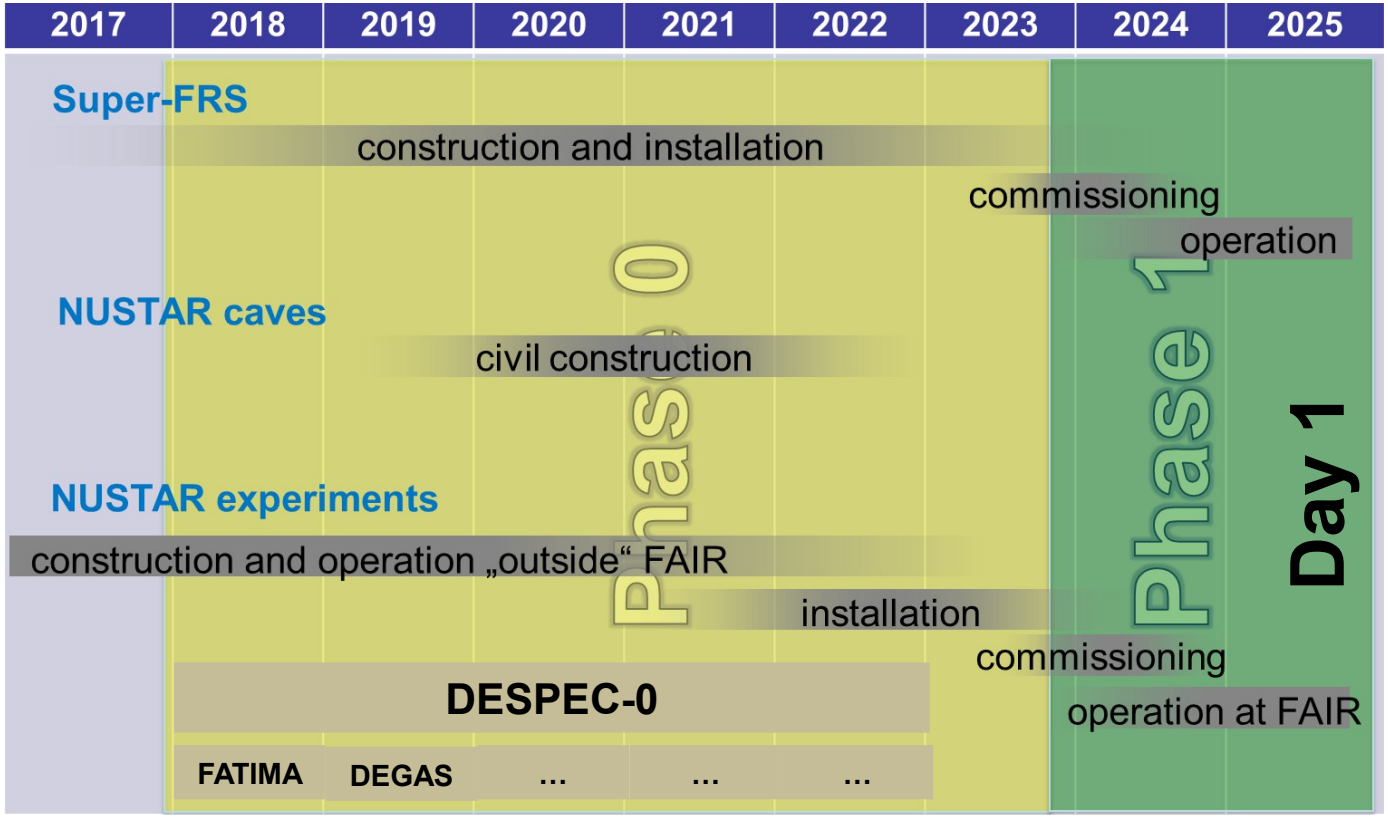
FATIMA in operation at GANIL



CSC coupled to MR-TOF tested at GSI

NUSTAR Overall Schedule





Total Absorbtion Spectroscopy

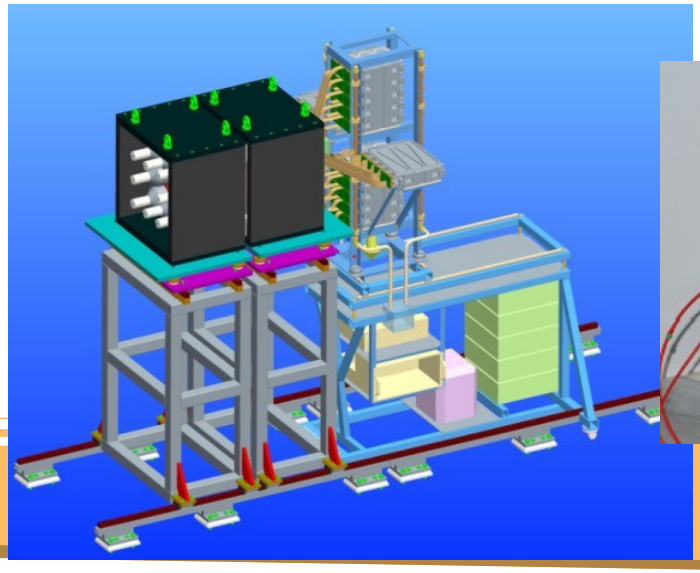
Spectroscopy of very exotic nuclei

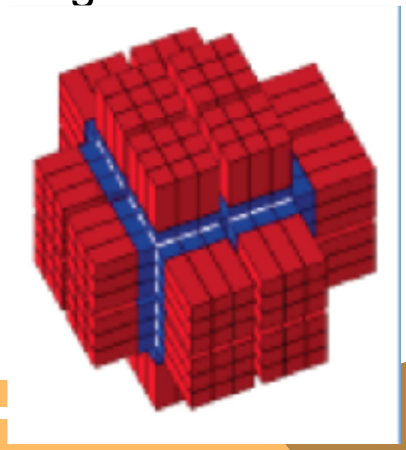
Complete β-decay level schemes, γγ-coincidences

K-Isomer spectroscopy

PARIS

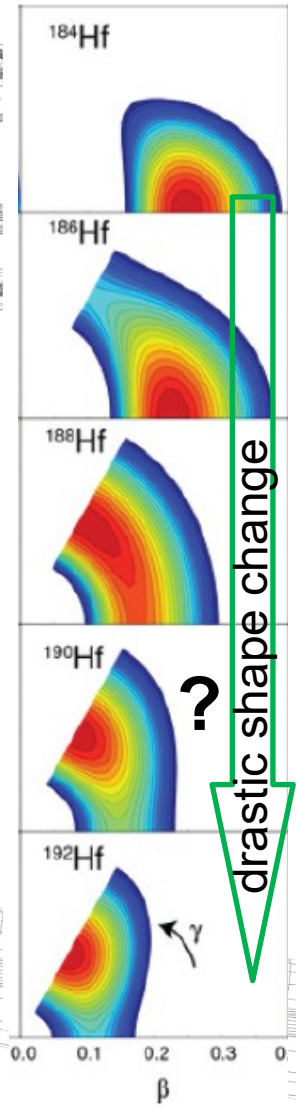
- Increased efficiency
- Better energy resolution
- Fast timing
- Complementing or replacing DTAS

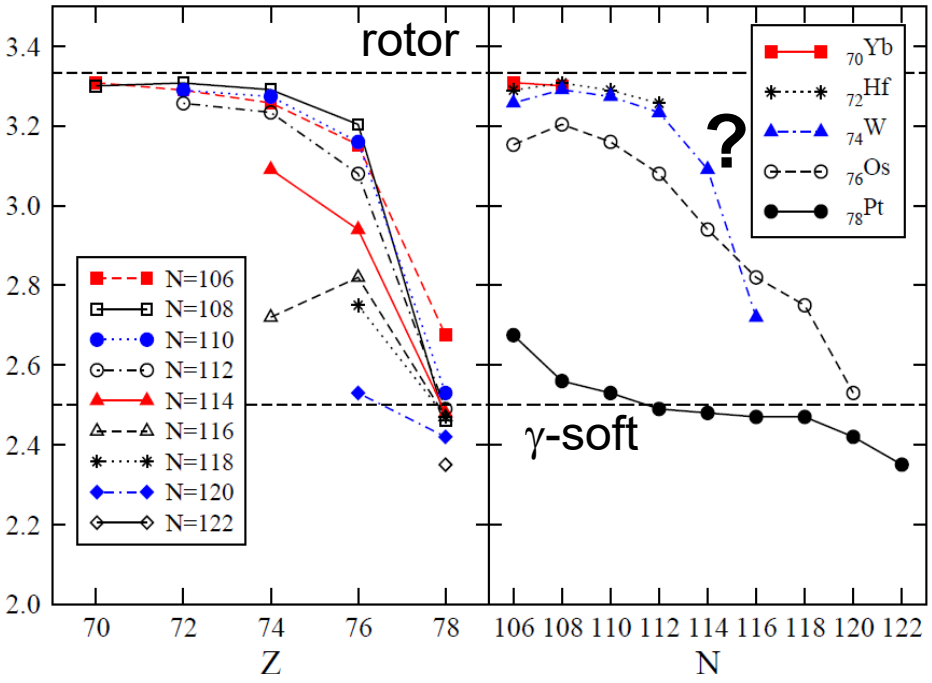


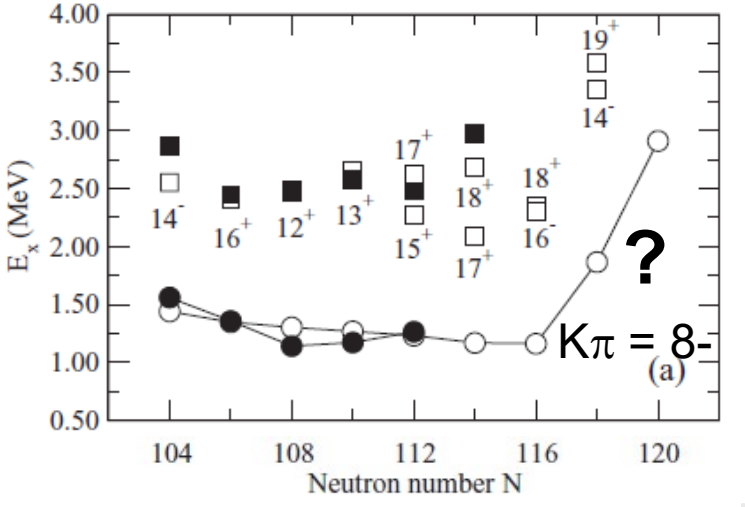


Structure of very n-rich Hf isotopes

- β decay lifetimes and strength distributions to refine the accuracy of r-process path calculations describing the mass abundance of heavy elements,
- level energies of excited states in hafnium isotopes to allow testing the predicted shape evolution from prolate to oblate with the critical point at N=116,
- K-isomer lifetimes to shed further light on the structure of the heaviest hafnium isotopes accessible







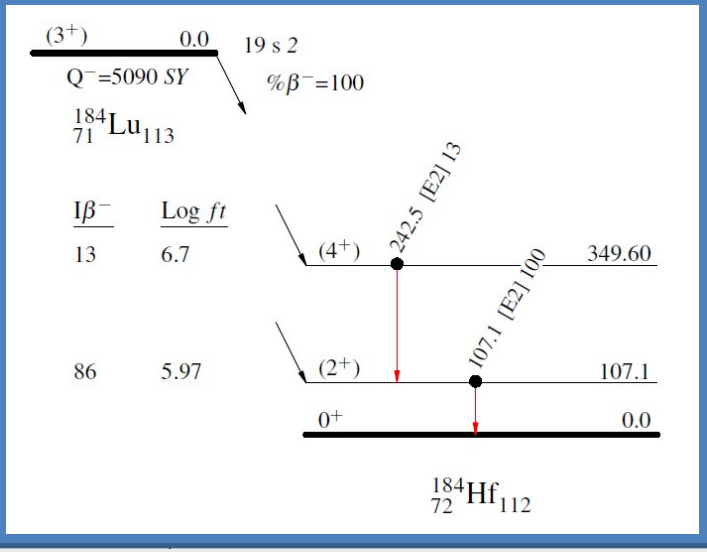
Experiment

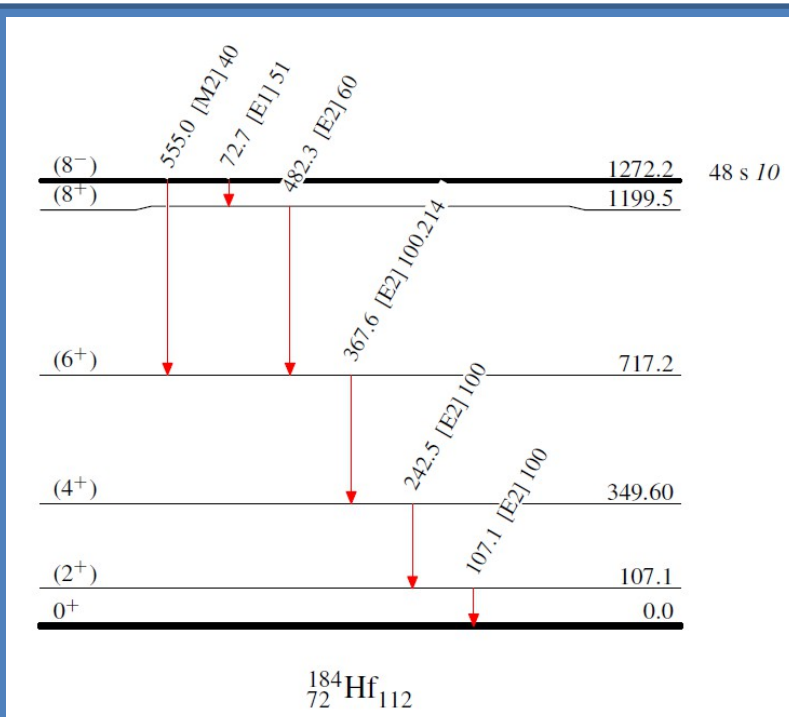
208Pb, 1 GeV/u → Be 4 g/cm2 → 188Lu, 0.26 nb → DESPEC – DTAS set-up

Setting optimized for
most n-rich Hf isotopes
from both
- Lu β decay into excited Hf states,
- Hf isomer decay (≈10% est. isomeric ratio)

γ yield / shift							
A	184	185	186	187	188	189	190
Hf		21	98	345	252	166	73
Lu	70	659	437	196	69		

Expected decay structure of the reference isotopes 184Hf



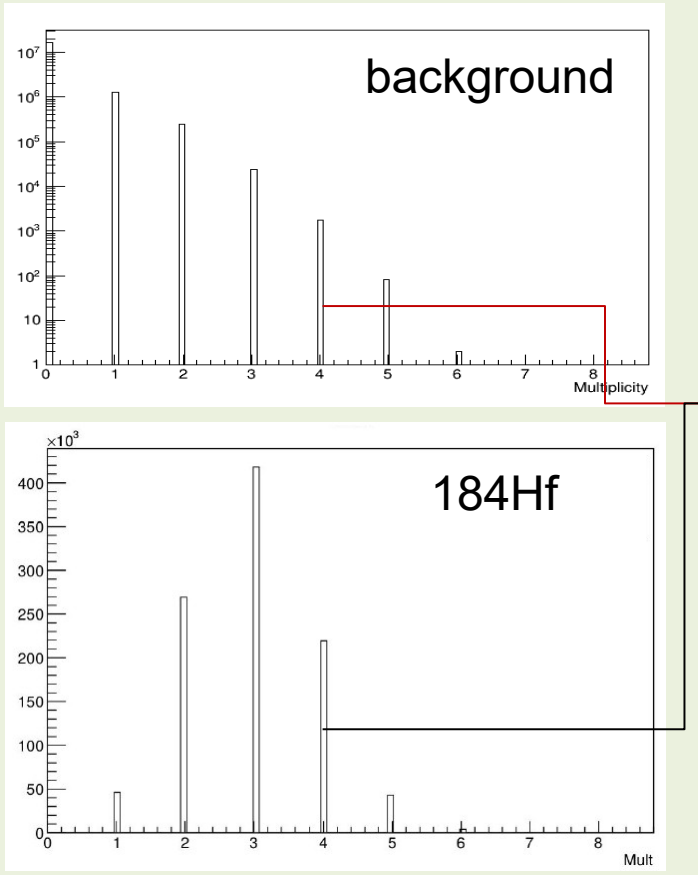


K-isomer background considerations

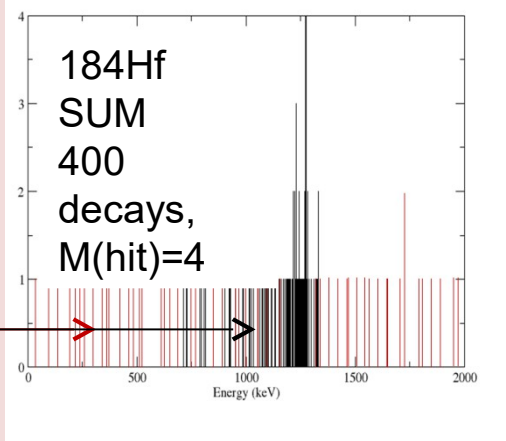
Isomeric decays produce no trigger like a β in AIDA. Therefore ambient background radiation becomes critical for rare and/or long lived isomers.

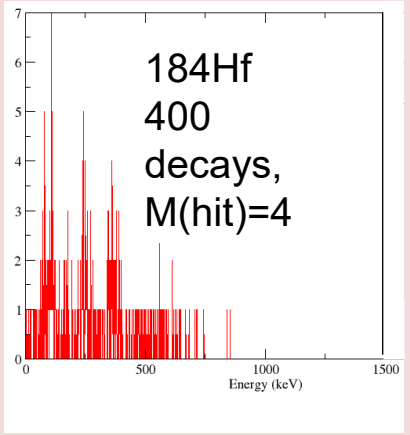
Novel approach: The multiplicity information provided by DTAS provides a selective trigger!

M(hit) distribution



Worst case scenario, corresponding to expected isomer yield of 190Hf!





2s isomers will be visible with <10 observed decays per hour!!!

GEANT simulations confirm efficient background suppression. To avoid multiplicity „pile-up“ by chance coincidences, a narrow time window is needed.

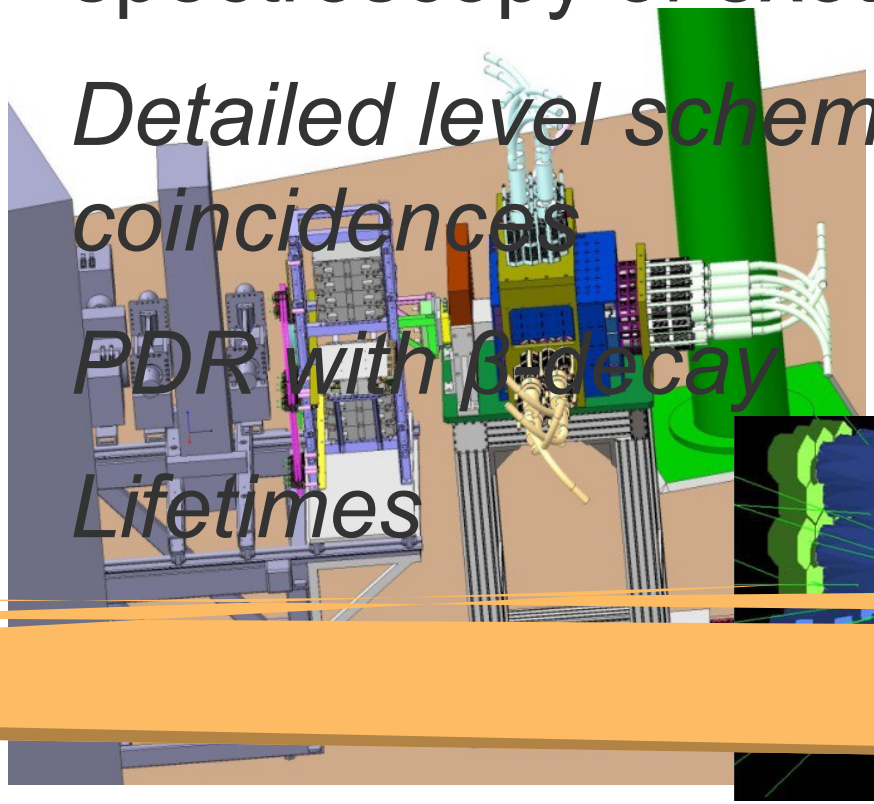
DEGAS Decay Spectroscopy

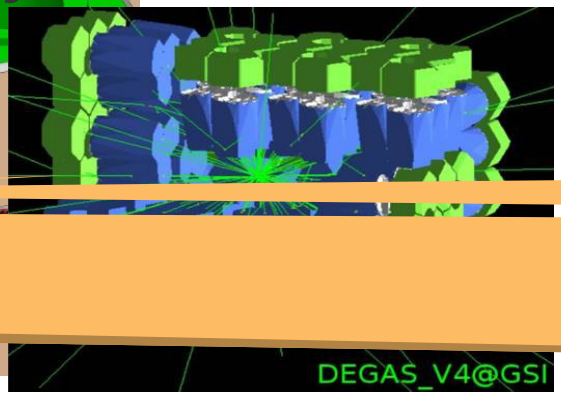
High-resolution decay spectroscopy of exotic nuclei

Detailed level schemes, $\gamma\gamma$-coincidences

PDR with β-decay

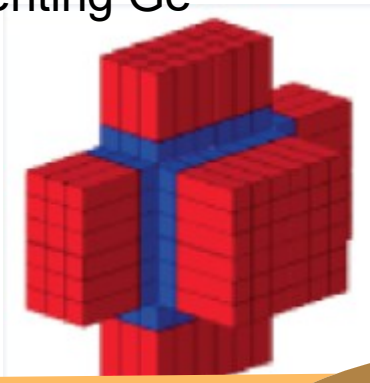
Lifetimes





PARIS

- Increased efficiency
- High efficiency at high energy
- Sufficient energy resolution
- Fast timing
- Complementing Ge



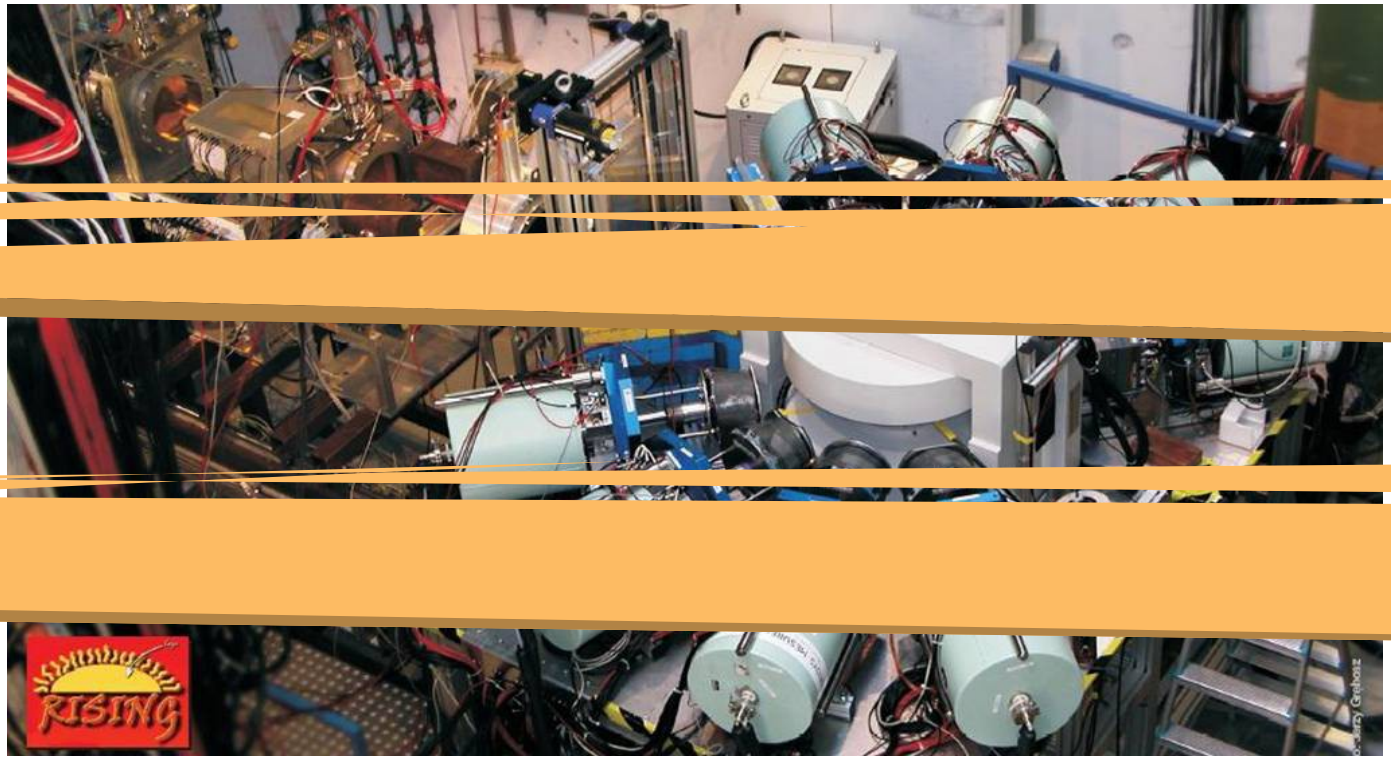
gSPEC Nuclear Moments

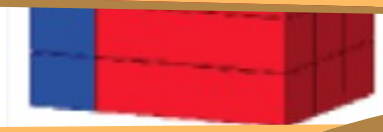
DESPEC Nuclear Moments

g-factors of exotic nuclei

PARIS

- Increased efficiency
- Sufficient energy resolution
- Complementing Ge

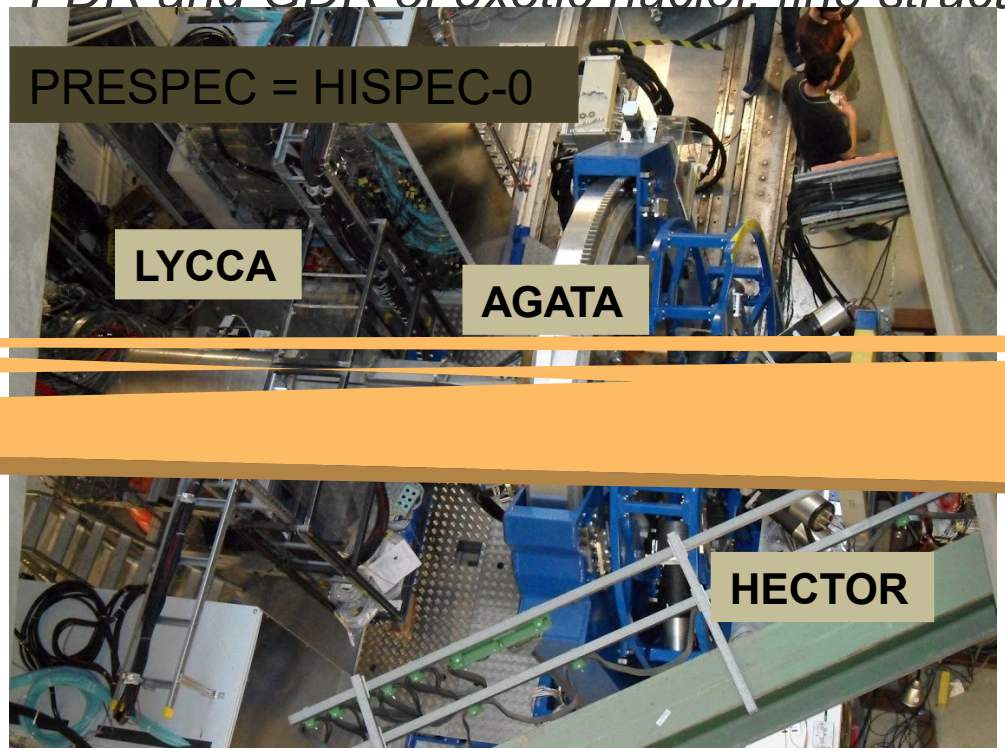




Dipole response of exotic nuclei

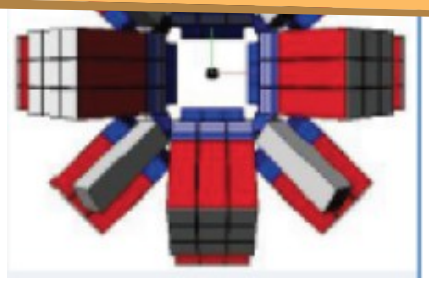
HISPEC In-Flight Spectroscopy at relativistic energies

PDR and GDR of exotic nuclei, fine structure



PARIS

- Increased efficiency
- Better energy resolution
- Better Doppler correction



Conclusions

FAIR is finally on schedule

GSI is back with the FAIR Phase-0 programme

Many Physics Opportunities at HISPEC/DESPEC with PARIS

- Total Absorbtion Spectroscopy
- Spectroscopy of very exotic (=rare) nuclei
- β-decay to PDR states

DESPEC: Decay Spectroscopy