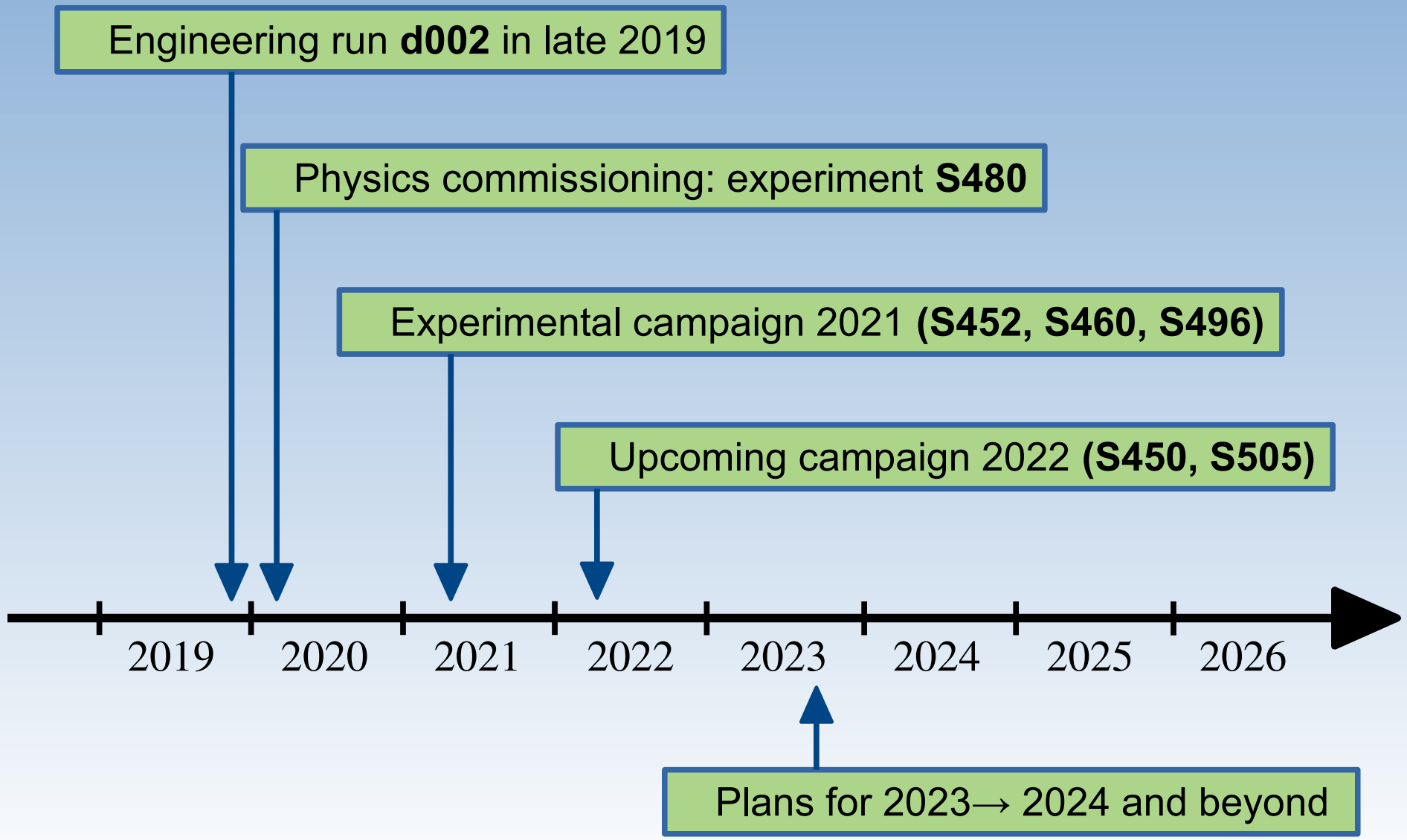
DESPEC experiments in FAIR Phase-0: from commissioning to early physics

Helena M. Albers, GSI Darmstadt

Outline

DESPEC Overview: physics goals, setup, subsystems



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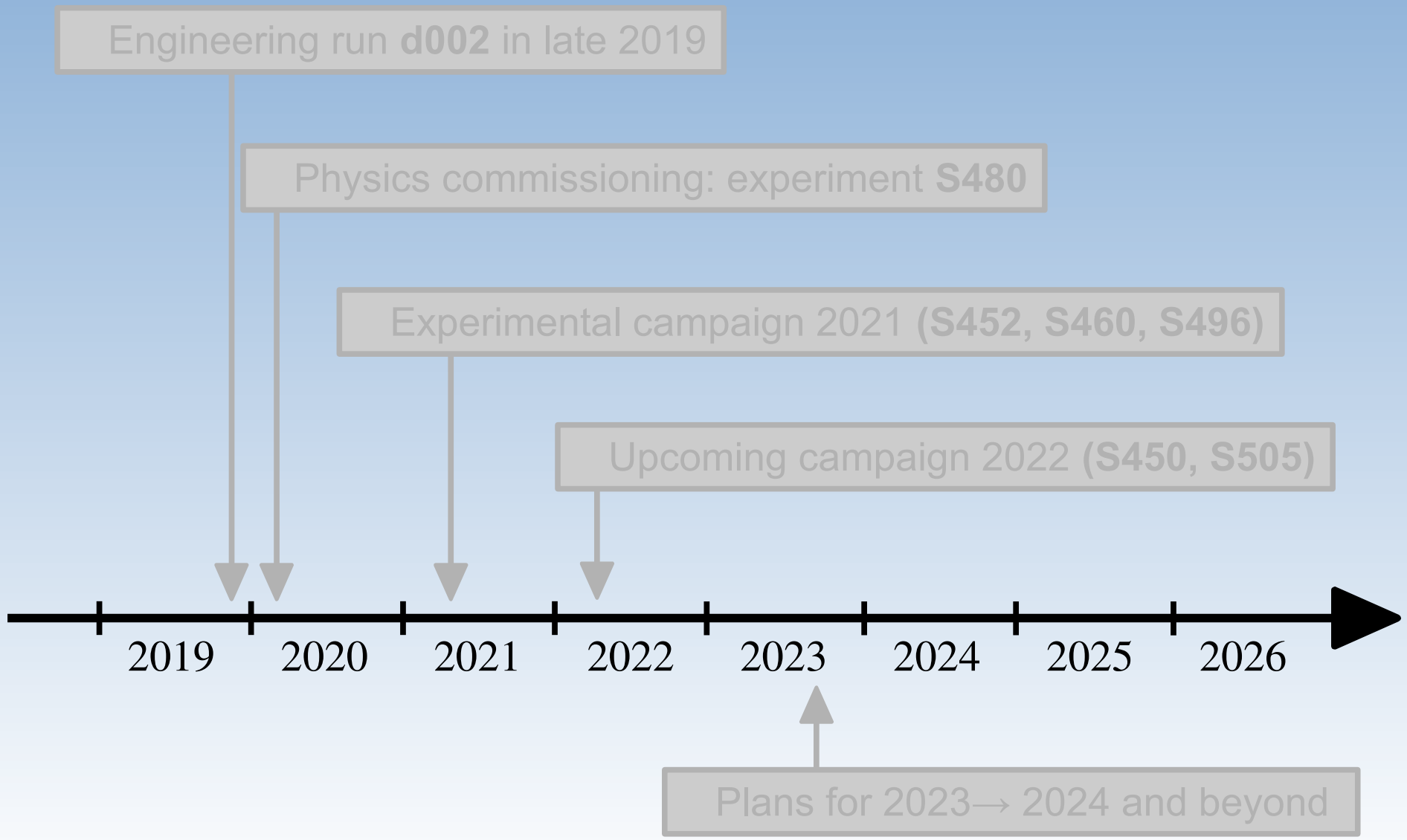
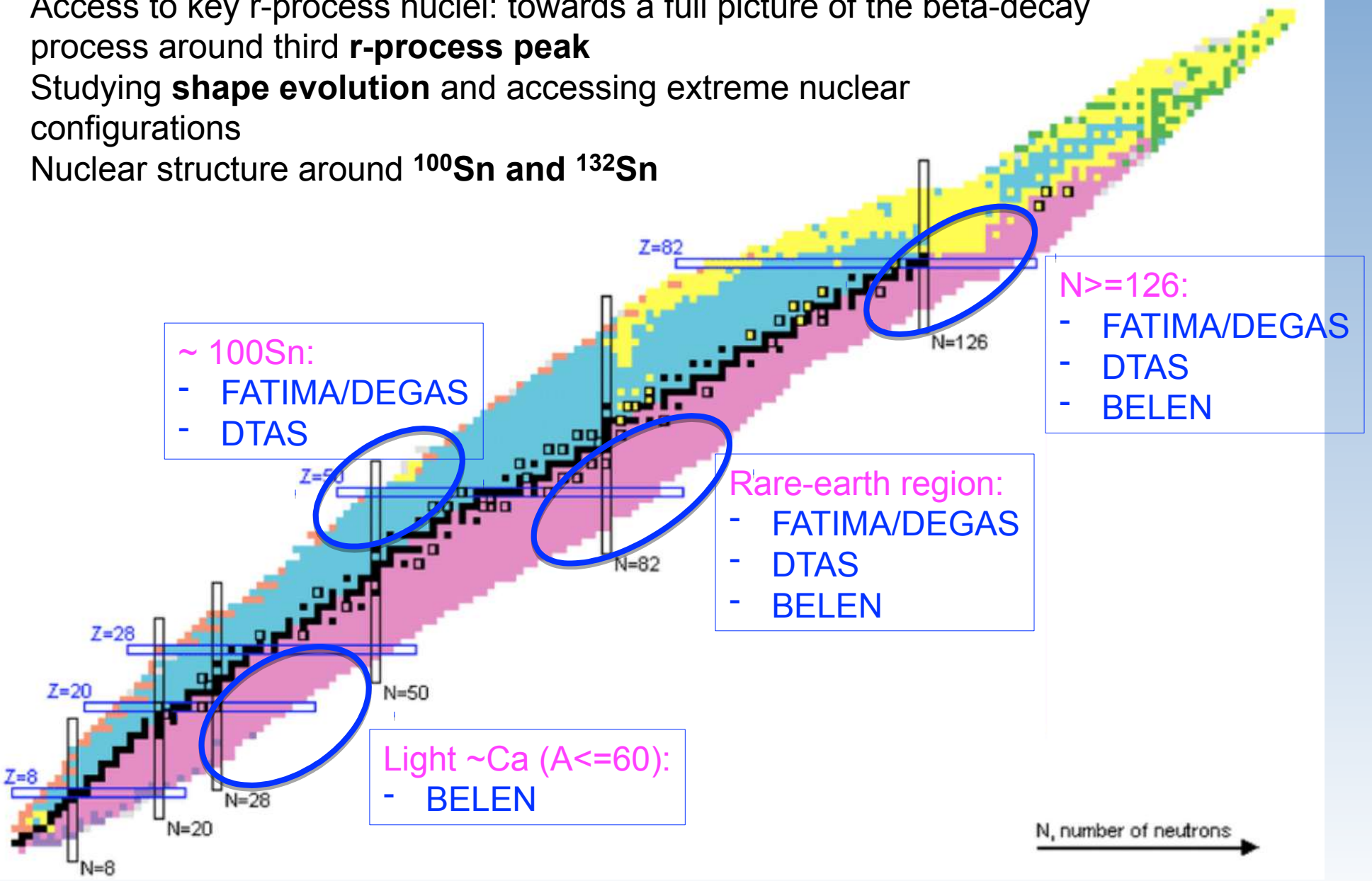


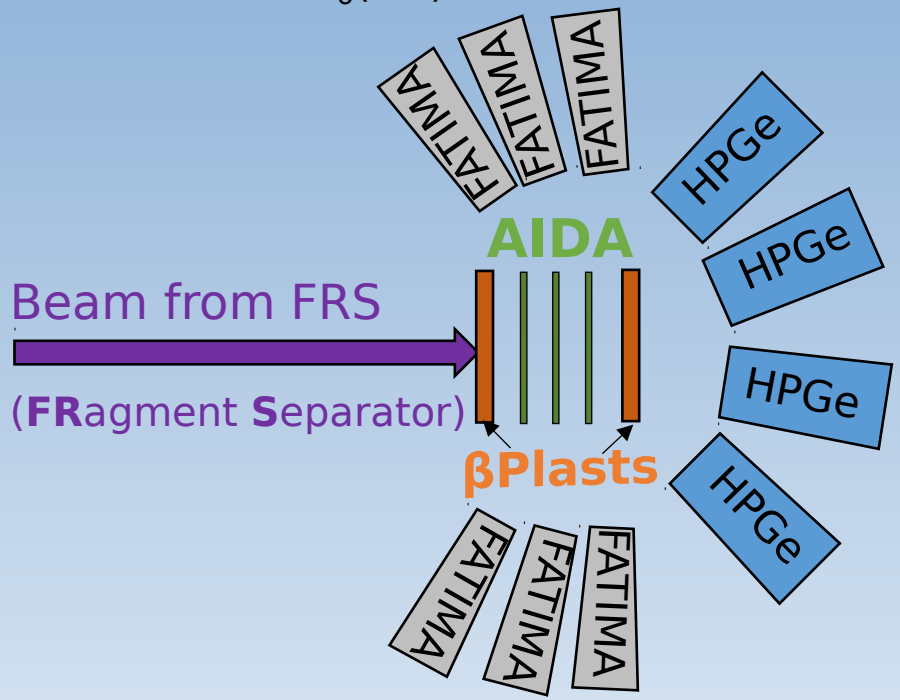
Physics goals and motivation

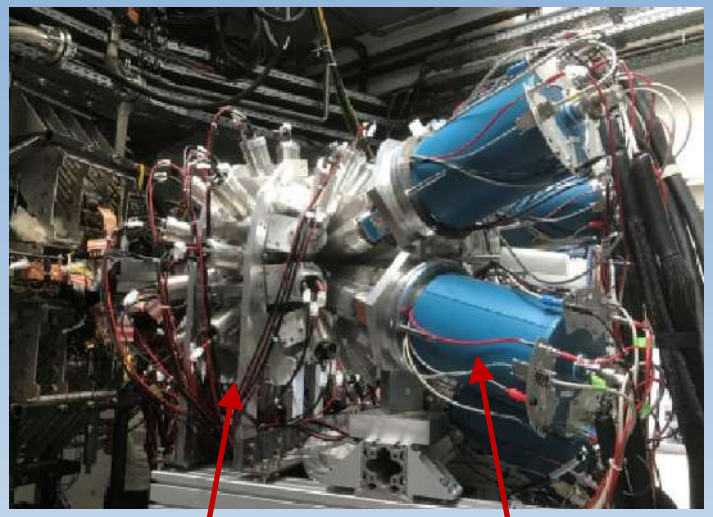
- Access to key r-process nuclei: towards a full picture of the beta-decay process around third **r-process peak**
- Studying **shape evolution** and accessing extreme nuclear configurations
- Nuclear structure around **^{100}Sn and ^{132}Sn**



DESPEC setup

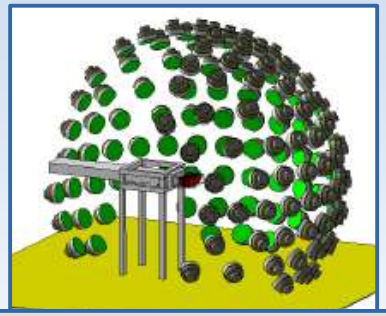
- DEcay SPECtroscopy with (Super-)FRS beams
- Implantation array **AIDA**: 2 or 3 highly-segmented DSSD layers
- **AIDA** sandwiched by two **βPlasts**: fast plastic scintillators
- **FATIMA** $LaBr_3(Ce)$ and **HPGe** detectors





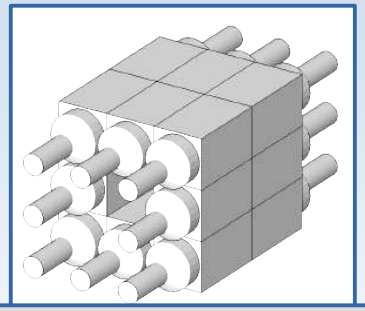
FATIMA modules

HPGe triple clusters

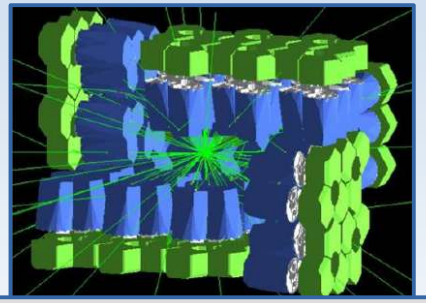


The MOdular Neutron SpectromeTER **(MONSTER)**

BEta-deLayEd Neutron detector **(BELEN)**
48 3He cylindrical counters

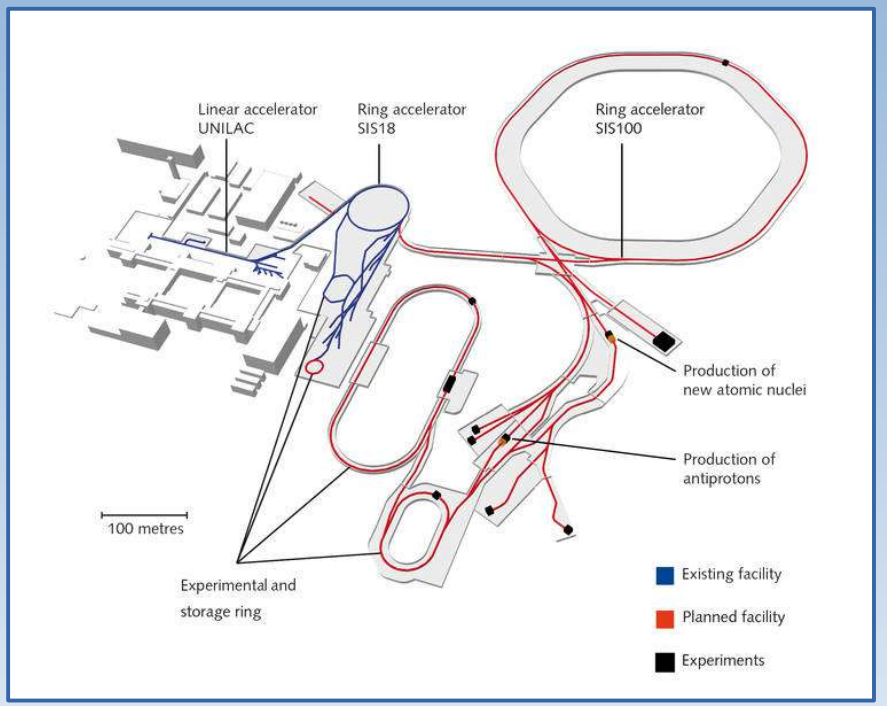


Decay Total Absorption γ-ray Spectrometer **(DTAS)**
NaI(Tl) modules

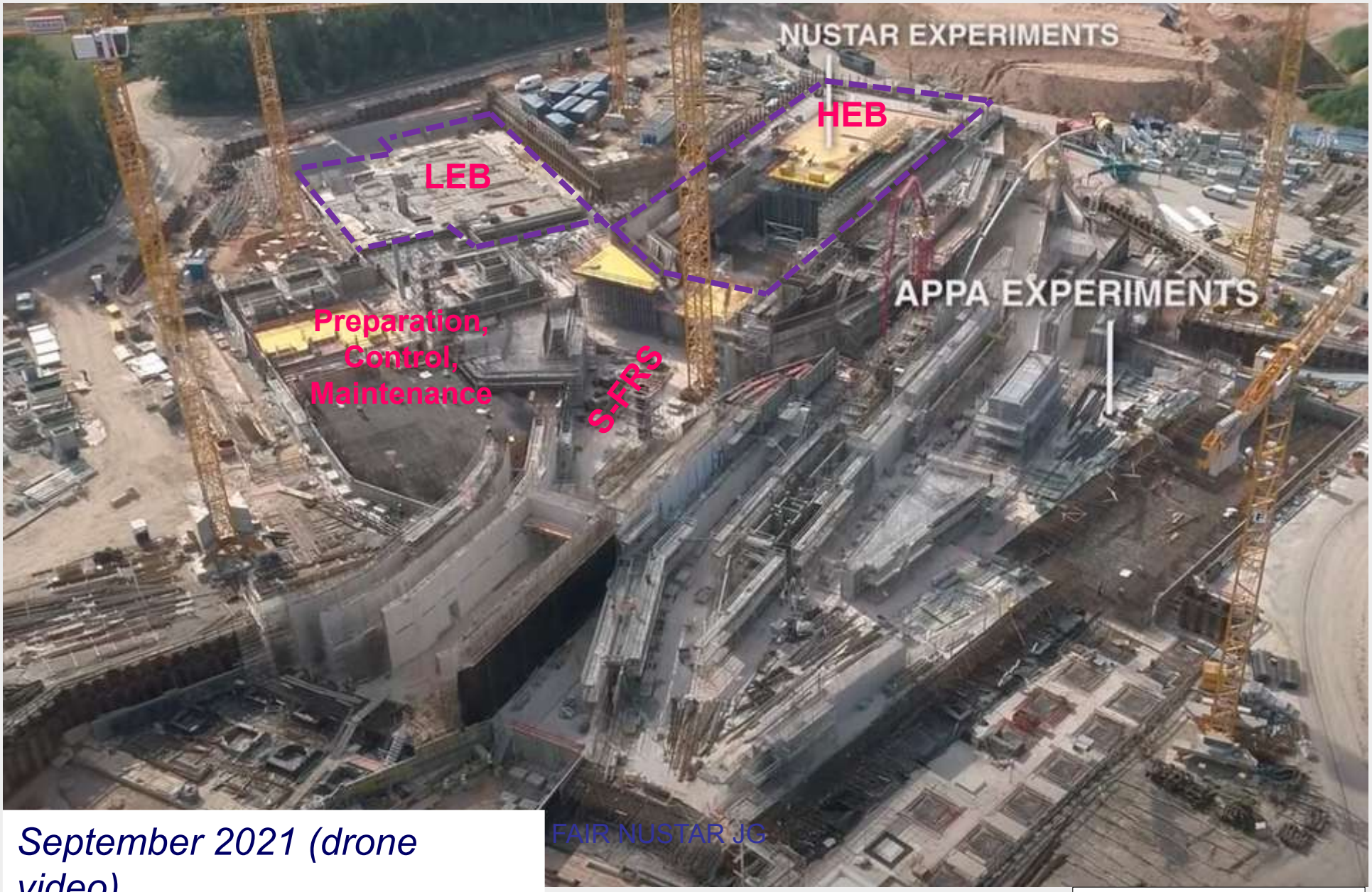


DESPEC Ge Array Spectrometer **(DEGAS)**
triple clusters

FAIR Construction



FAIR Construction

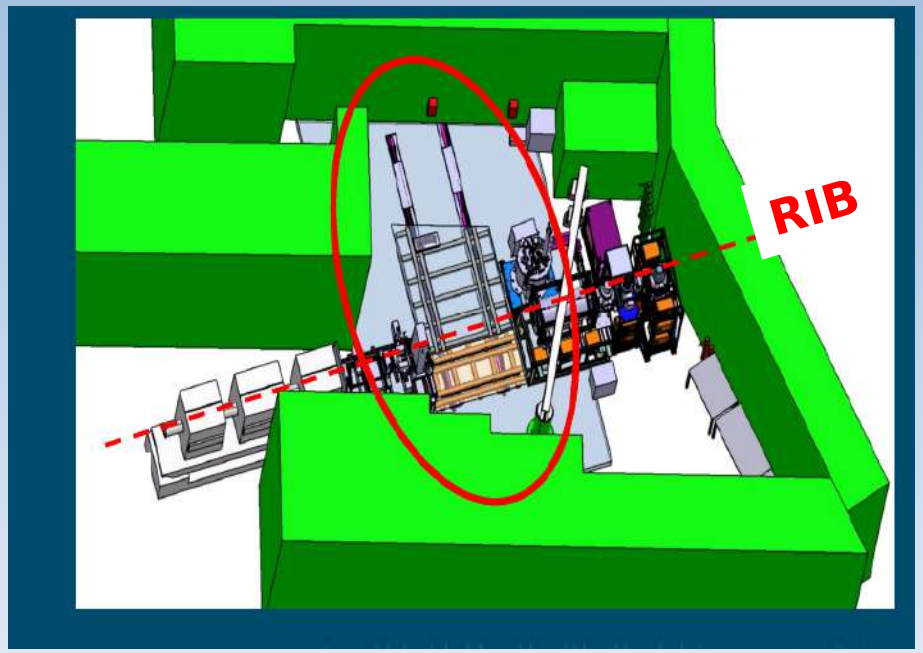


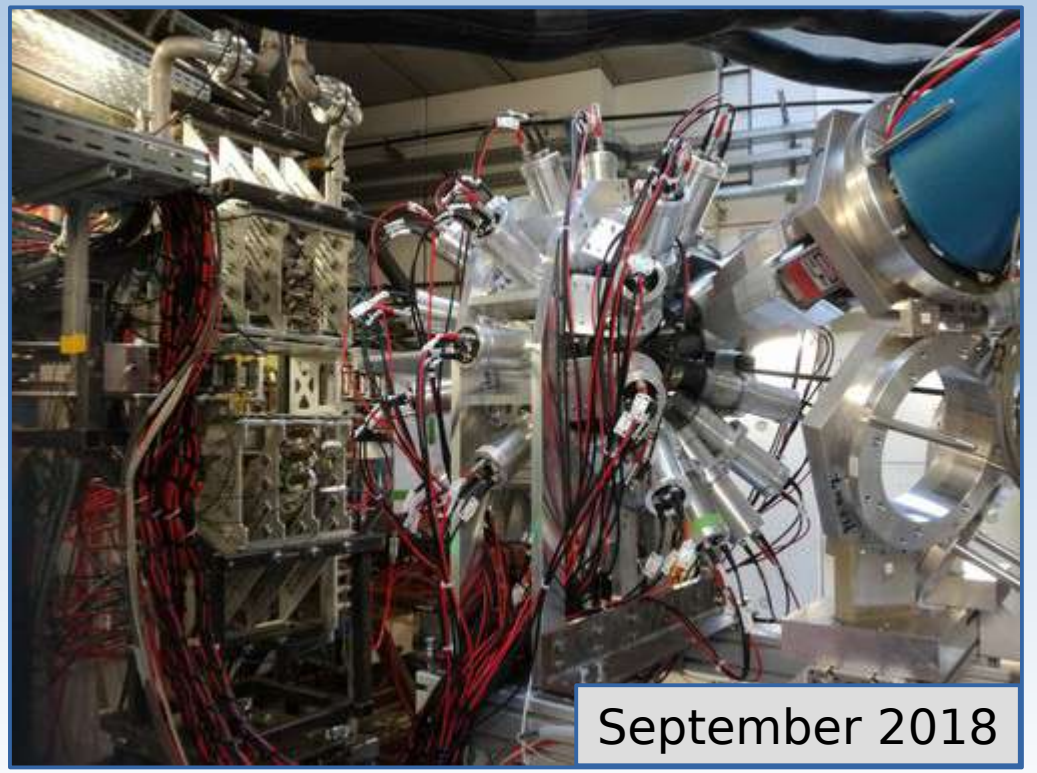
September 2021 (drone video)

Courtesy of J. Gerl

DESPEC @ GSI, S4 area

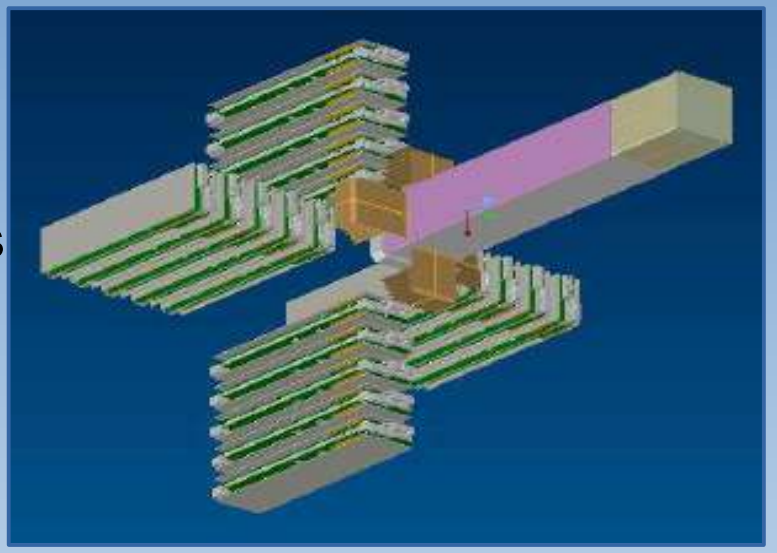
- Beamline at S4, shared by FRS Ion Catcher
- Moving platform on rails
- Platforms: IFJ Krakow, TIRF Mumbai

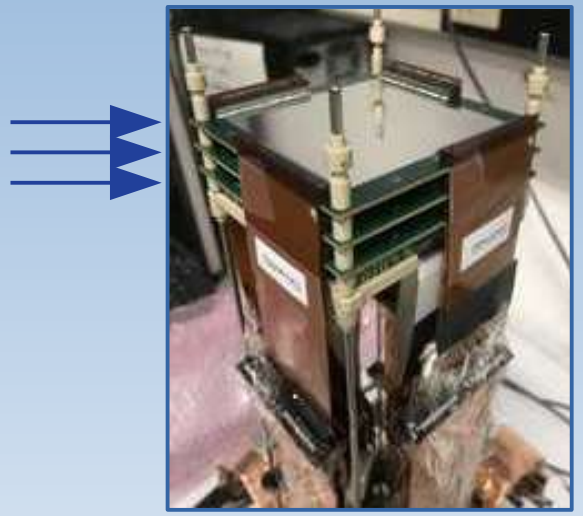




Subsystems - AIDA

- The ***A***dvanced ***I***mplantation ***D***etector ***A***rray (Edinburgh, Daresbury, Liverpool)
- Stack of 1-mm thick DSSDs
- ‘Narrow’ (8x8 cm^2) or ‘wide’ (24x8 cm^2) geometries

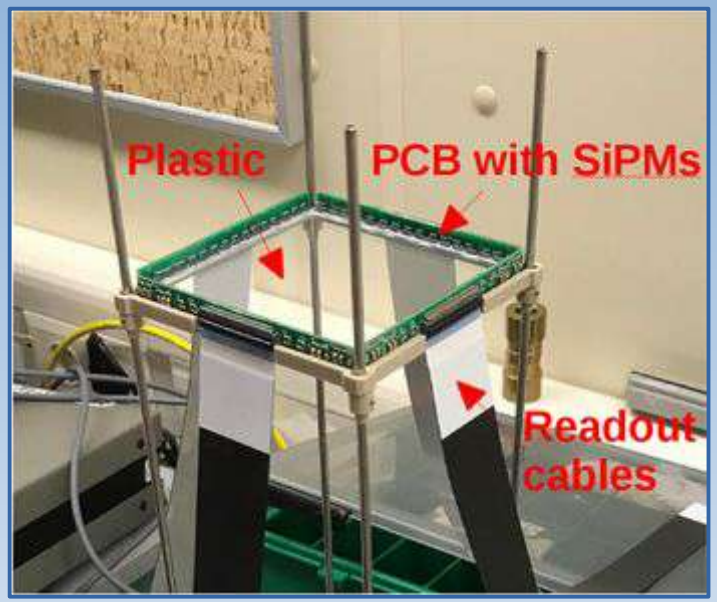




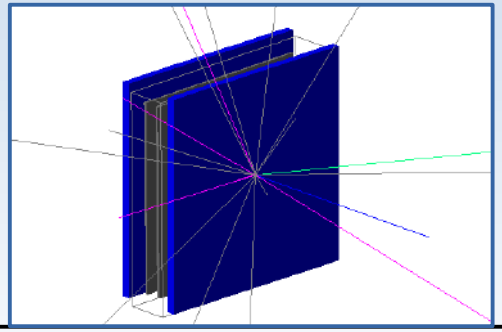
- Dedicated ASIC chips allow **large dynamic range**
- **Implants**: multi-GeV; **Decays**: tens-of-keV → MeV
- Triggerless DAQ, high data throughput
- Fast recovery time <40μs

Subsystems - βPlast

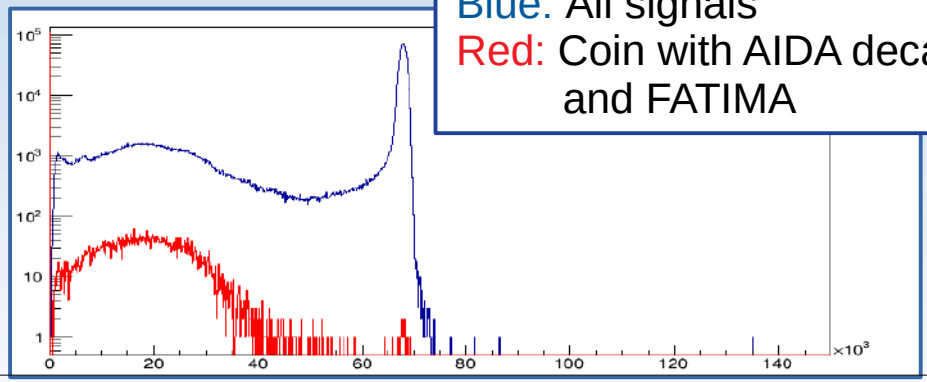
- The βPlast detectors: 3-mm thick plastic scintillators - UWS, GSI
- SiPMs at the edges coupled to readout channels
- Processed using in-house TAMEX electronics



- Two 8x8-cm^2 (or 24x8-cm^2) detectors sandwiching AIDA
- Excellent timing resolution (~100s ps)



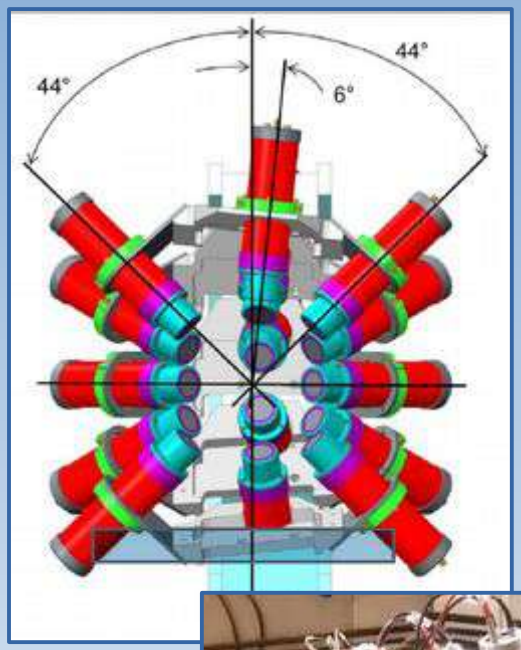
GEANT4 simulation using NPTool (M.Chishti *et al.*)

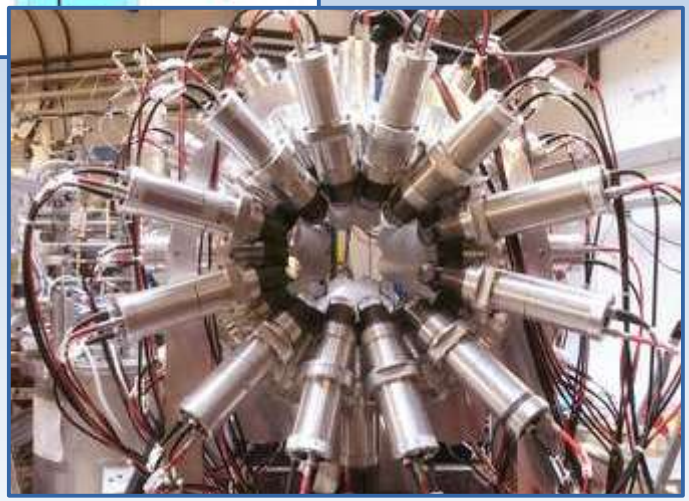


βPlast Time-over-Threshold (ToT) distributions

Subsystems - FATIMA

- ***FA***st ***TIM***ing ***A***rray of $LaBr_3(Ce)$ detector modules
- Brighton, Surrey, IFIN-HH, Cologne, Daresbury, Madrid, Manchester…

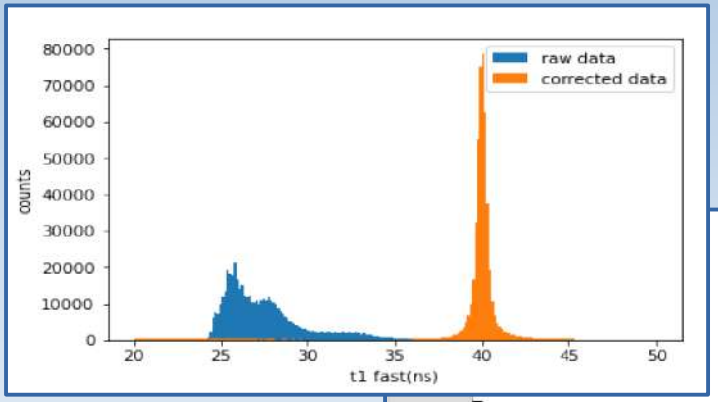




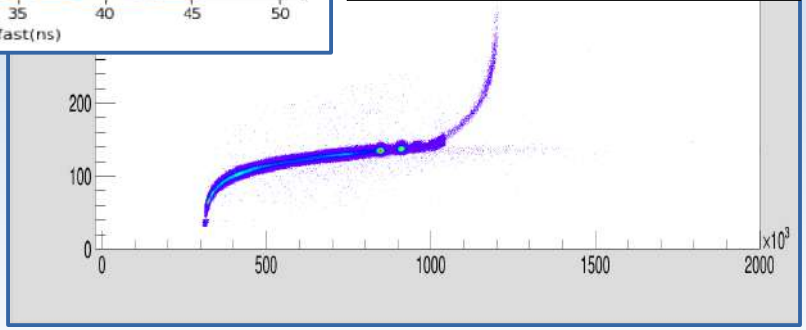
- New In-house new TAMEX4 frontend
- M. Wiebusch, H. Heggen, N. Kurz *et al.* GSI EE

Two amplifiers:
- 'slow' branch for **linear energy** ($TOT_{slow} \propto E$)
- 'fast' branch for **logarithmic energy** ($TOT_{fast} \propto \log(E)$)

Leading-edge timing from fast branch



Correlation between linear and logarithmic front-end branches



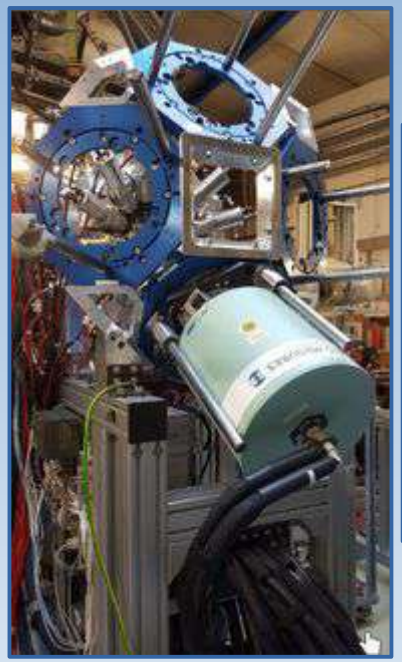
- Longer collection windows (>100us) and shorter deadtimes c.f. VME

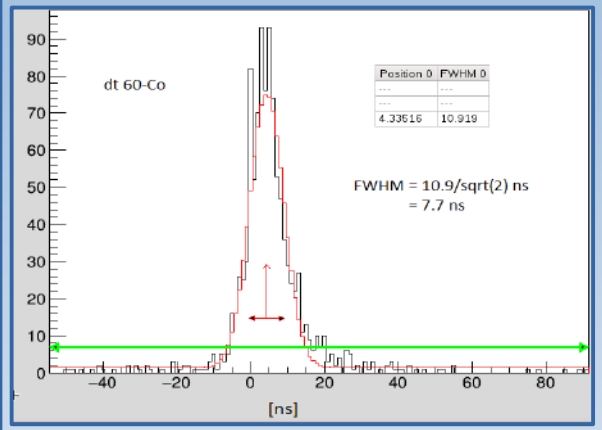
M.Rudigier *et al.*, NIM A 969, 163967 (2020)

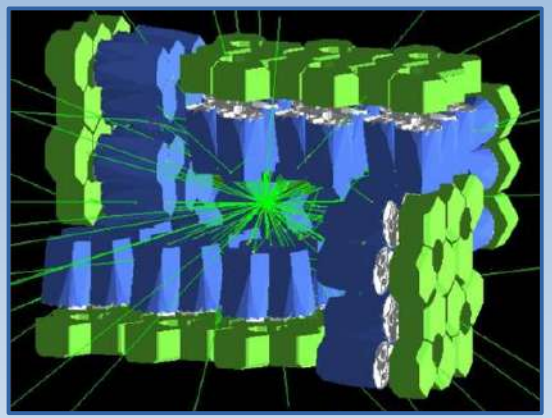
Subsystems: HPGes

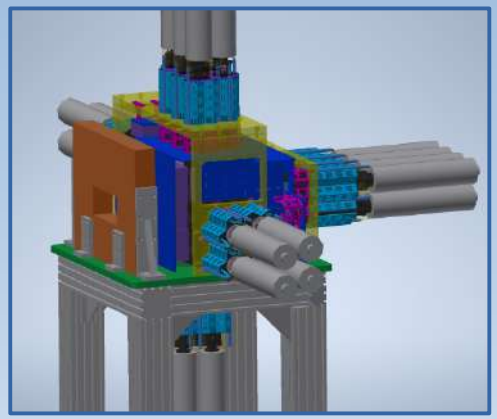
- **Past campaigns: "C2"/"C4" configurations**
- 7-fold Euroball Cluster detectors
- FEBEX4 Digital Readout
- New CFD for <10ns timing (H. Schaffner)

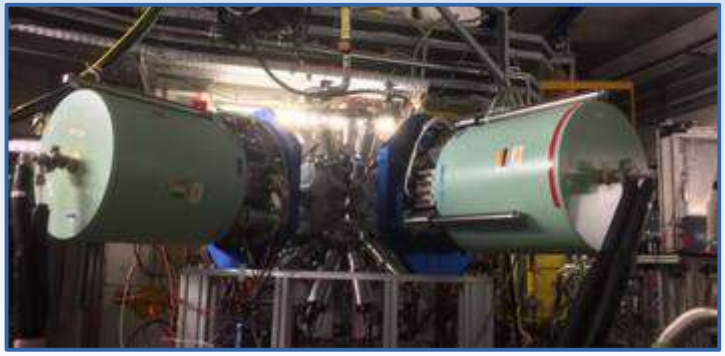
- **Future campaigns 2022+:**
- **28 DEGAS triple clusters**
- Experiment S450 (2022) → 'wide' AIDA + βPlast + DEGAS
- 18% efficient @ 1.3 MeV

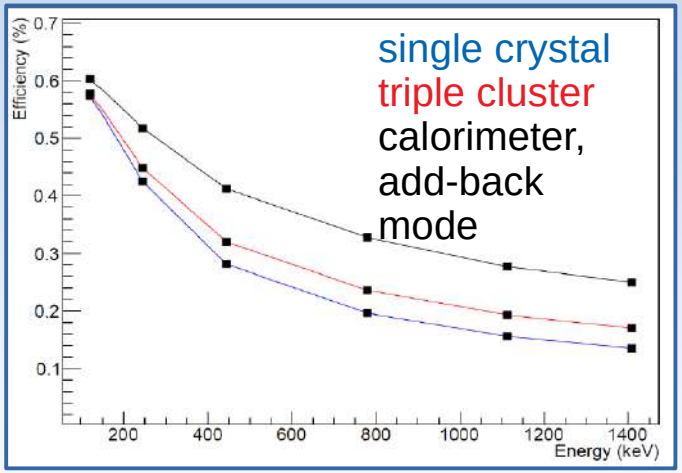






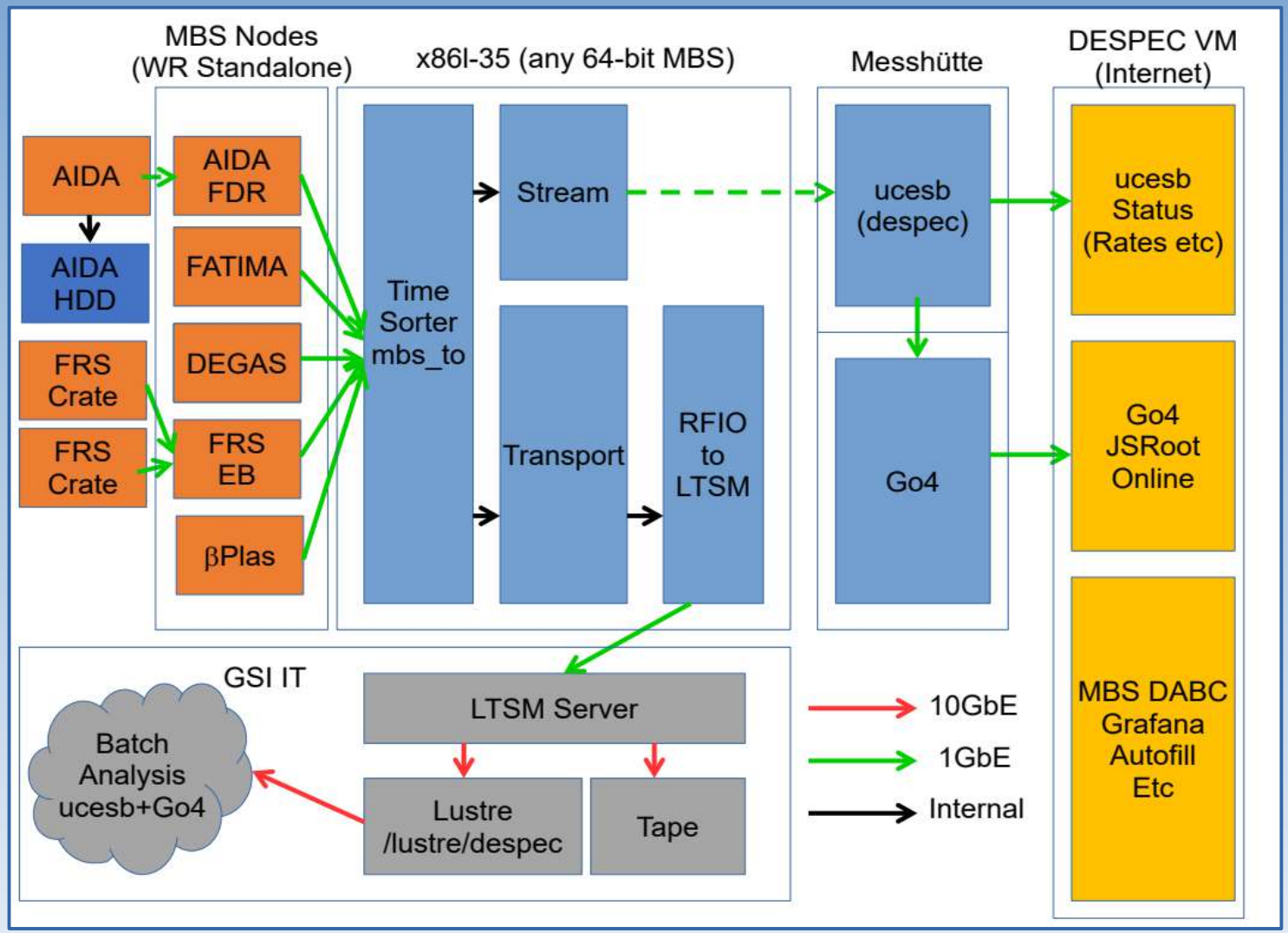






I. Kojouharov, P. Hermann, D. Hien, A. Banerjee, H. Schaffner, A. Yaneva, M. Mikolajczuk,...

DAQ architecture



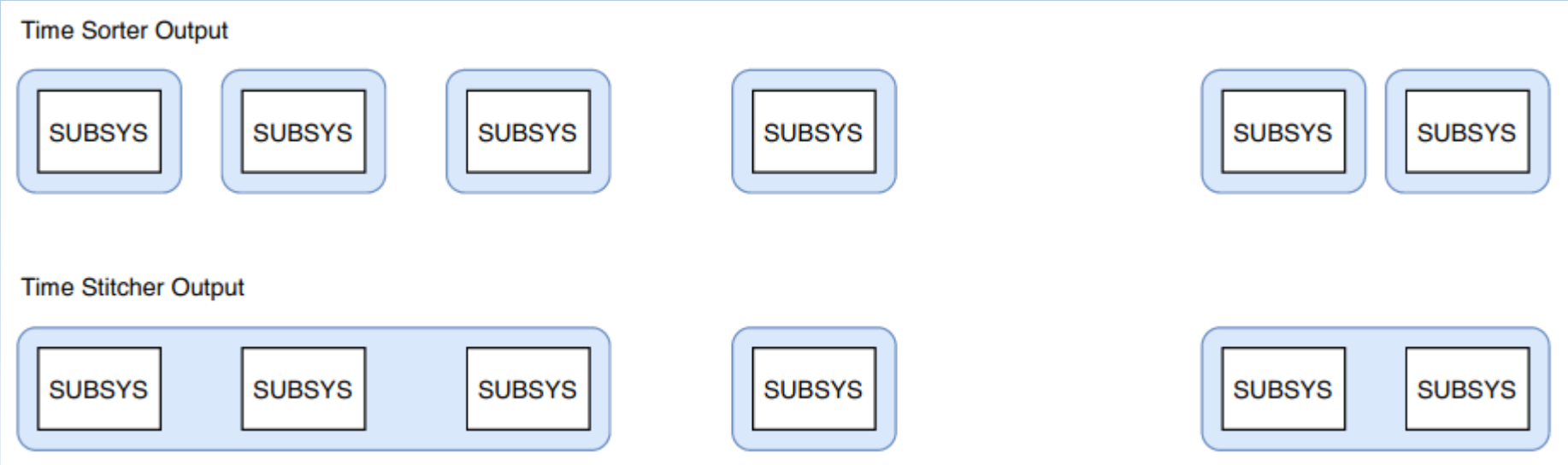
- *White Rabbit (WR) timestamping (correlations)*
- *2 Hz pulser (data throughput and synchronisation)*
- *"Time Machine" for synchronisation*

Key DAQ features:

- *SC41 (FRS) signal into subsystem DAQs*
- *Optional prompt flash trigger suppression*
- *Beam structure monitoring*

Data Acquisition – Timestitching with ucesb

- **‘ucesb’** - **u**npack and **c**heck **e**very **s**ingle **b**it
- General purpose data unpacker
- Carries out event building after timesorting
- Number of different methods investigated for optimisation
- Special treatment of “multihit” events



Courtesy of N.Hubbard

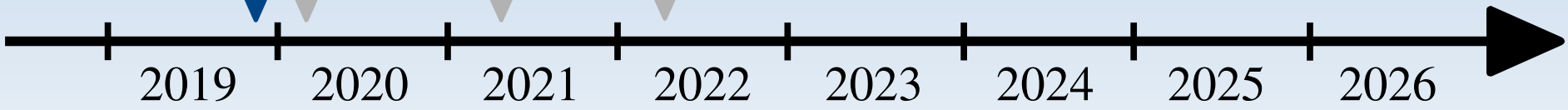
DESPEC Overview: physics goals, setup, subsystems

Engineering run **d002** in late 2019

Physics commissioning: experiment **S480**

Experimental campaign 2021 **(S452, S460, S496)**

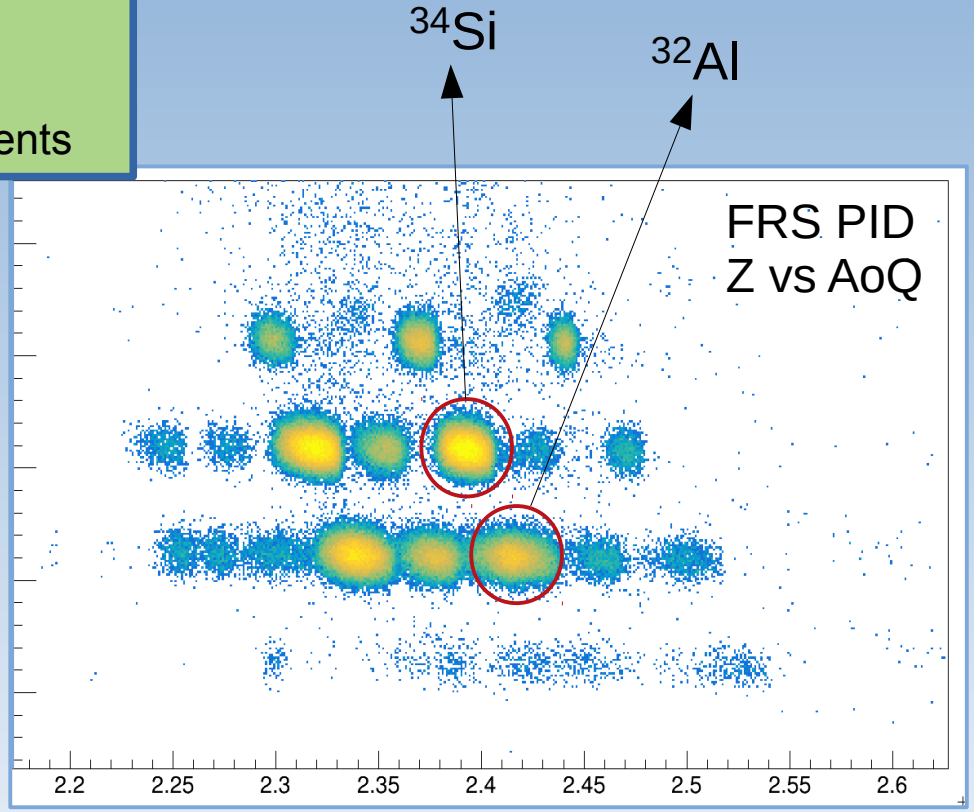
Upcoming campaign 2022 **(S450, S505)**



Plans for 2023→ 2024 and beyond

Engineering run **d002**

- Aims:
  - Check hardware performance
  - Individual DAQs under beam conditions
  - WR timestamp synchronisation
  - Debugging online Go4 analysis
  - Provide data for development of offline sorting
  - Regaining experimental experience, training of students

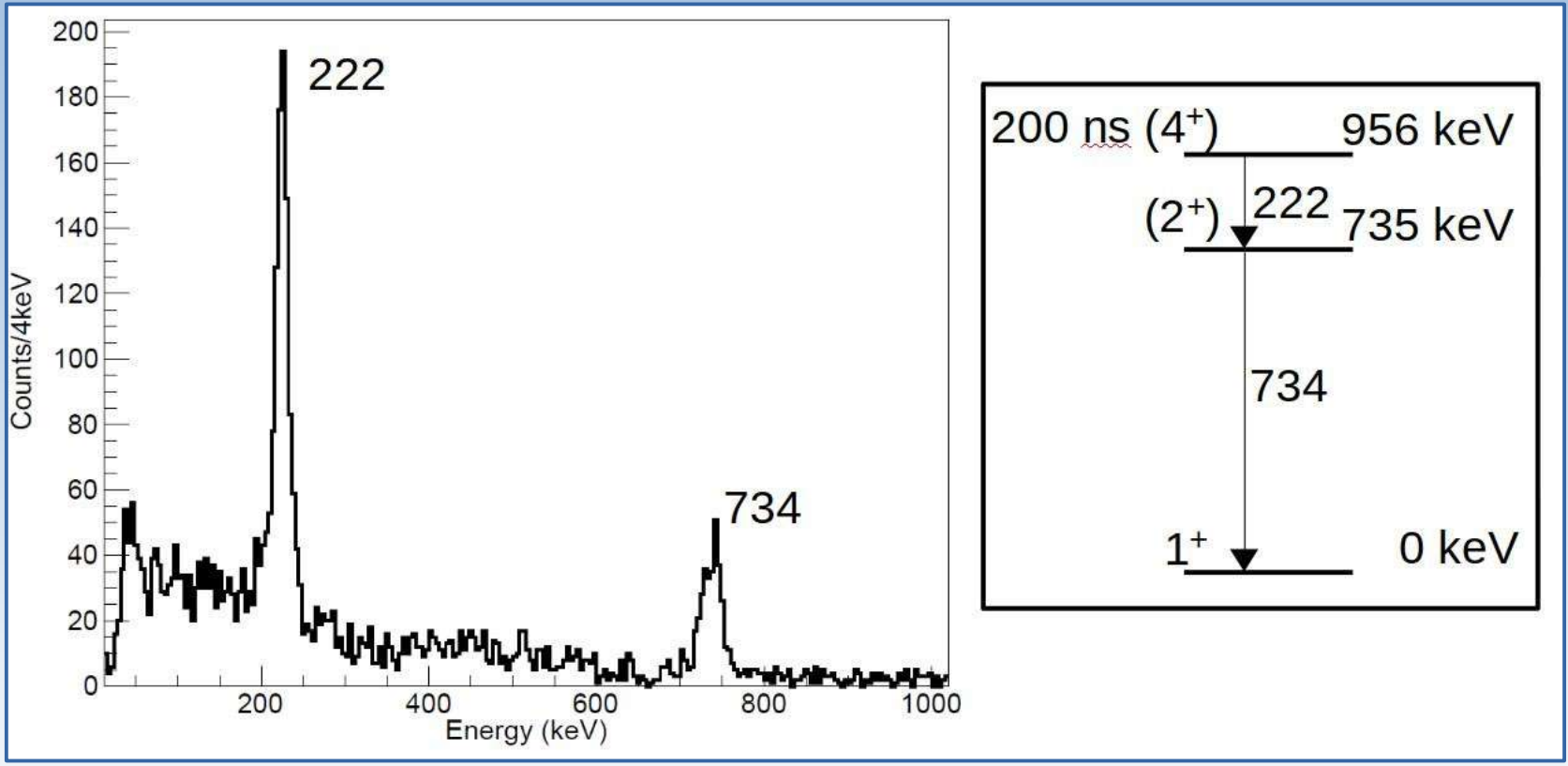


- **Ar** primary beam
- Fragments centred on **Si**
- U beam with **Re** fragments

Engineering run **d002**

- Successful data collection over two time periods
- Synchronisation with WR confirmed
- Isomeric state in ^{32}Al observed

Uses SC41(FRS)-FATIMA timing

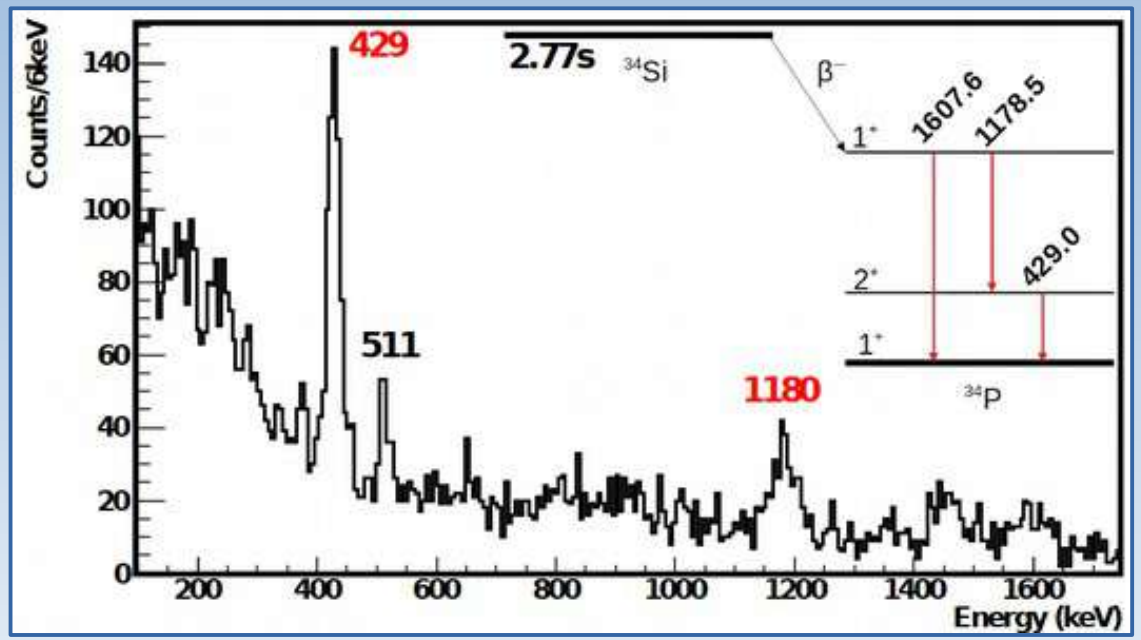


FATIMA spectrum measured after ^{32}Al implantation

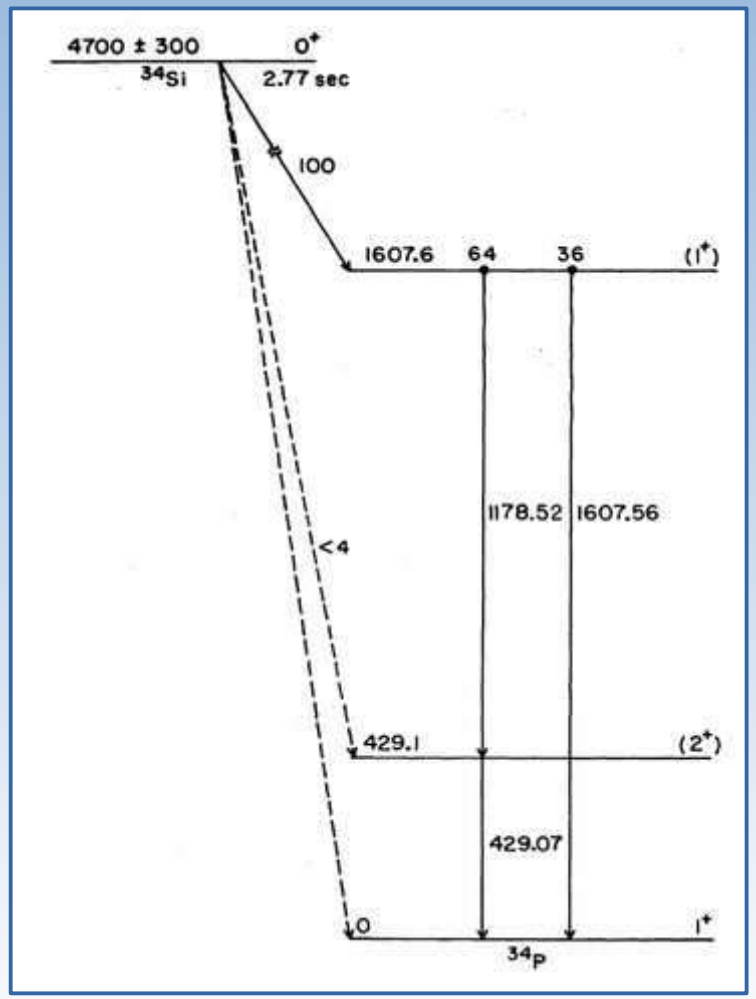
Engineering run **d002**

- Identification of beta-delayed gammas in ^{34}P following implantation of ^{34}Si

- Uses FRS coin AIDA for implants
- AIDA coin βPlast and γs for decays
- Optimised correlation parameters



FATIMA spectrum measured in coincidence with β decays from implanted ^{34}Si



A.M.Nathan and D.E.Allburger
Phys. Rev. C **15**,4 (1977)

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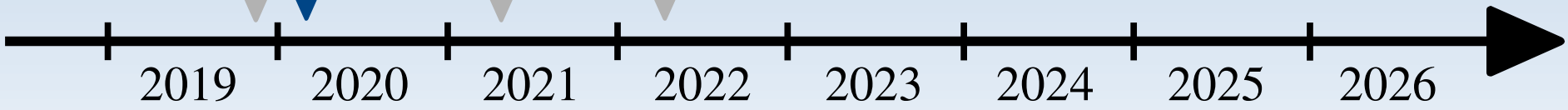
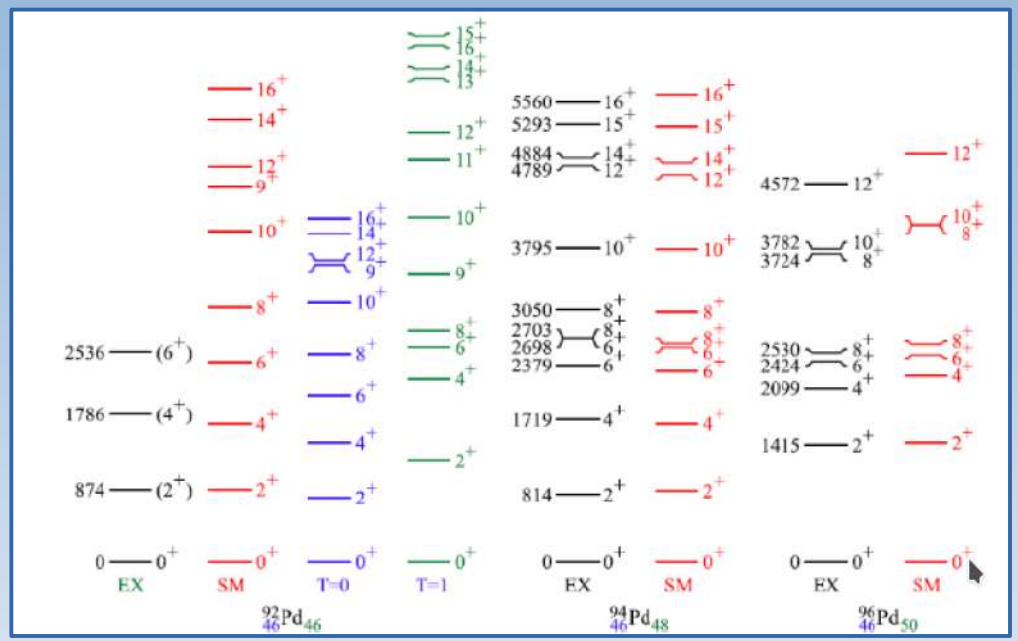


Plans for 2023→ 2024 and beyond

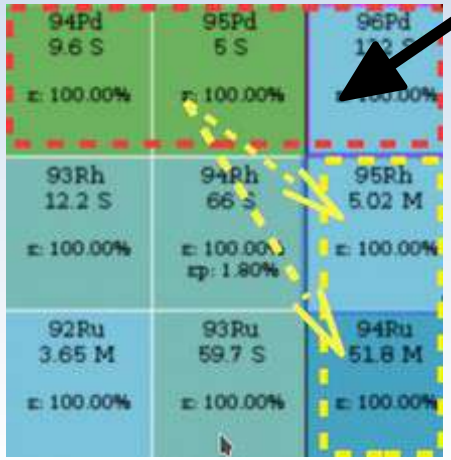
Physics commissioning experiment S480

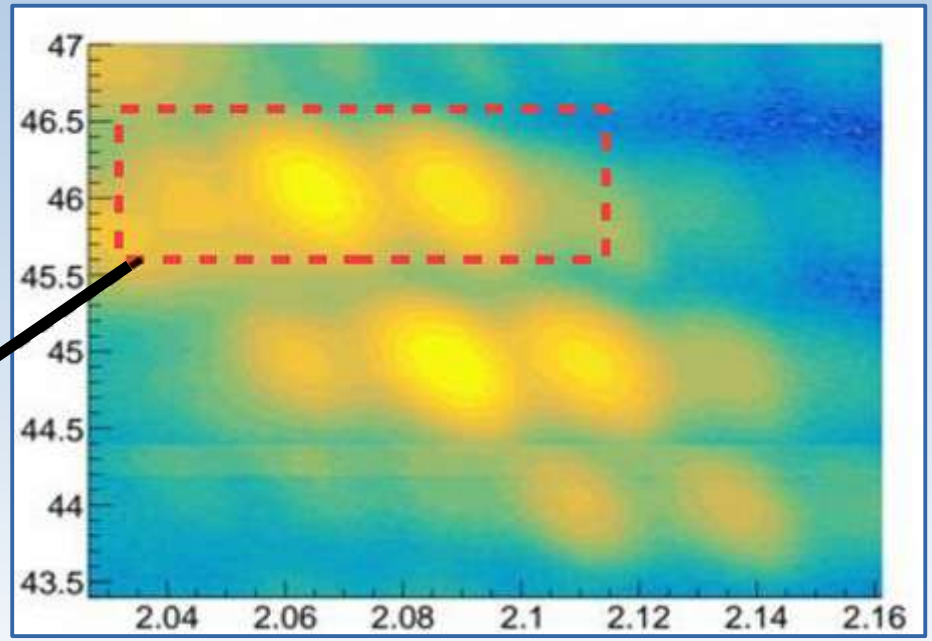
- Proposal submitted for ^{124}Xe primary beam
- Spokespersons: Gorska (GSI), Regan (Surrey), Cederwall (KTH), Jolie (Cologne)

Structure of the heaviest N=Z nuclei: Seniority Transitions and EM Transition Rates in ^{94}Pd



Lifetime analysis of ^{94,96}Pd
$6^+/8^+$ states underneath 14^+ isomer
Many other nuclei of interest
(^{95}Pd, ^{96}Ag, ...)

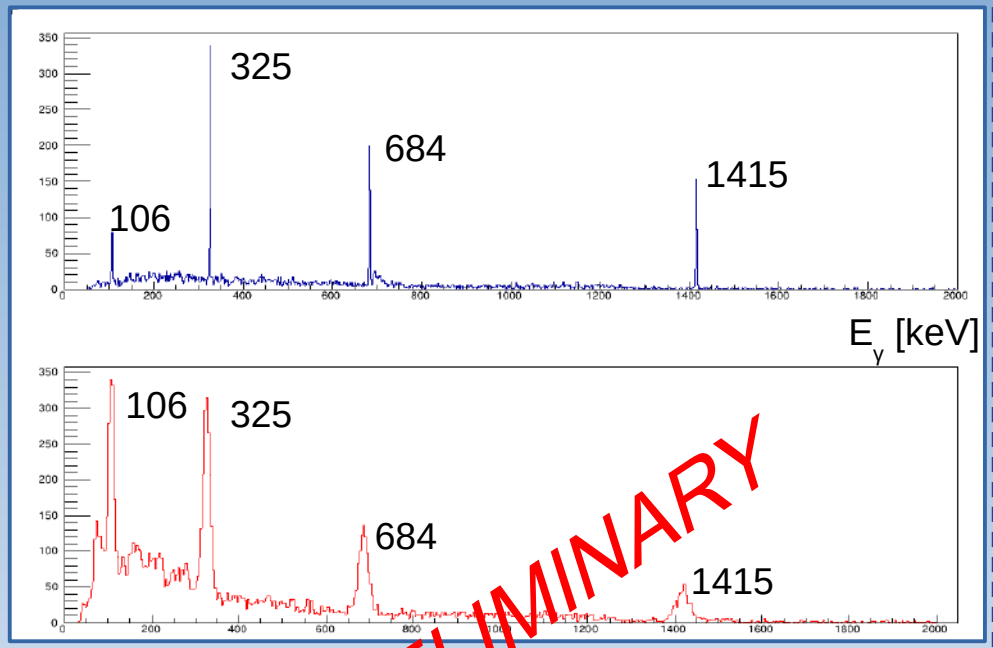


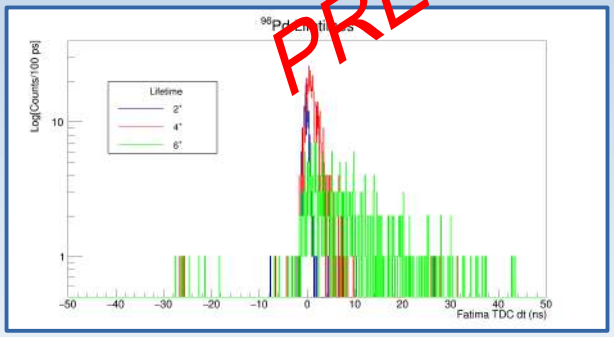


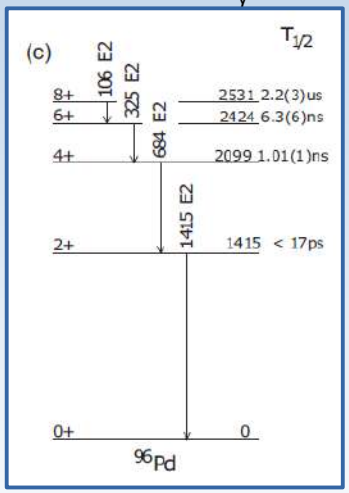
B. Das, S. Jazrawi, M. Mikolajczuk, A. Mistry, A. Yaneva

Physics commissioning experiment S480

- ^{96}Pd GALILEO HPGes and FATIMA

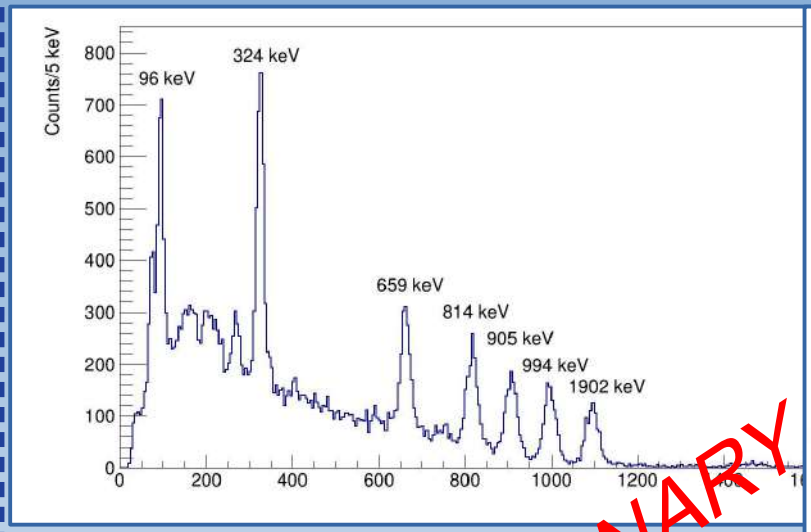


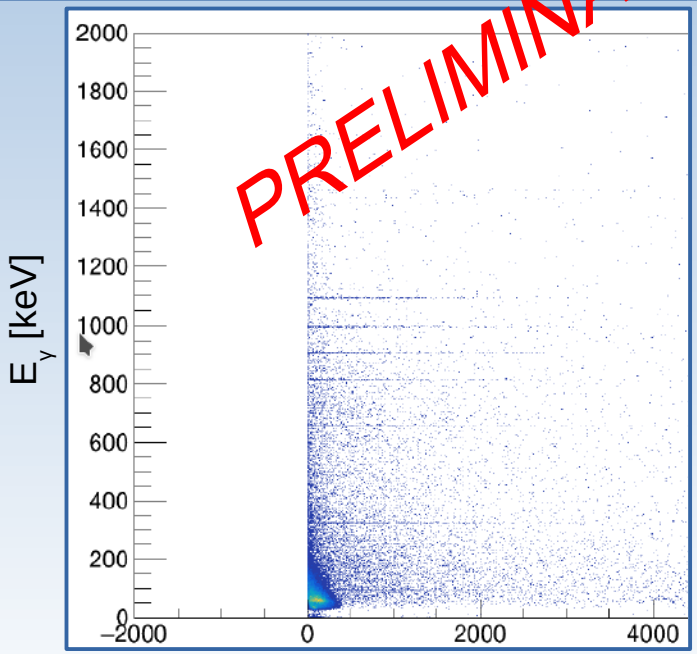


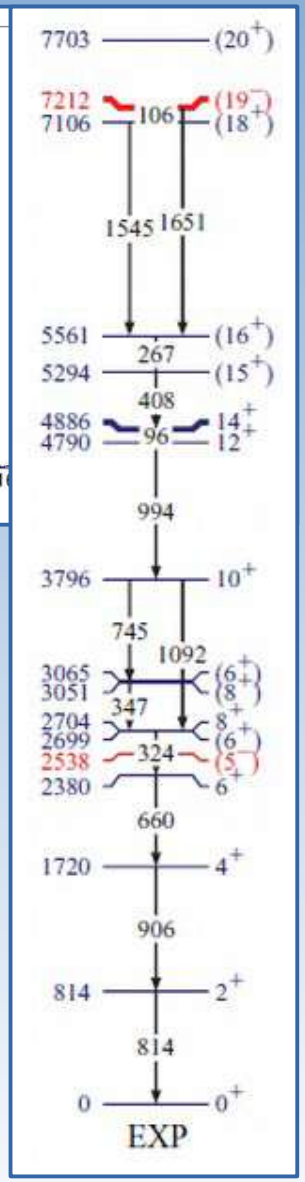


H. Mach *et al.*, PRC **95**, 014313 (2017)

- ^{94}Pd PID-gated FATIMA





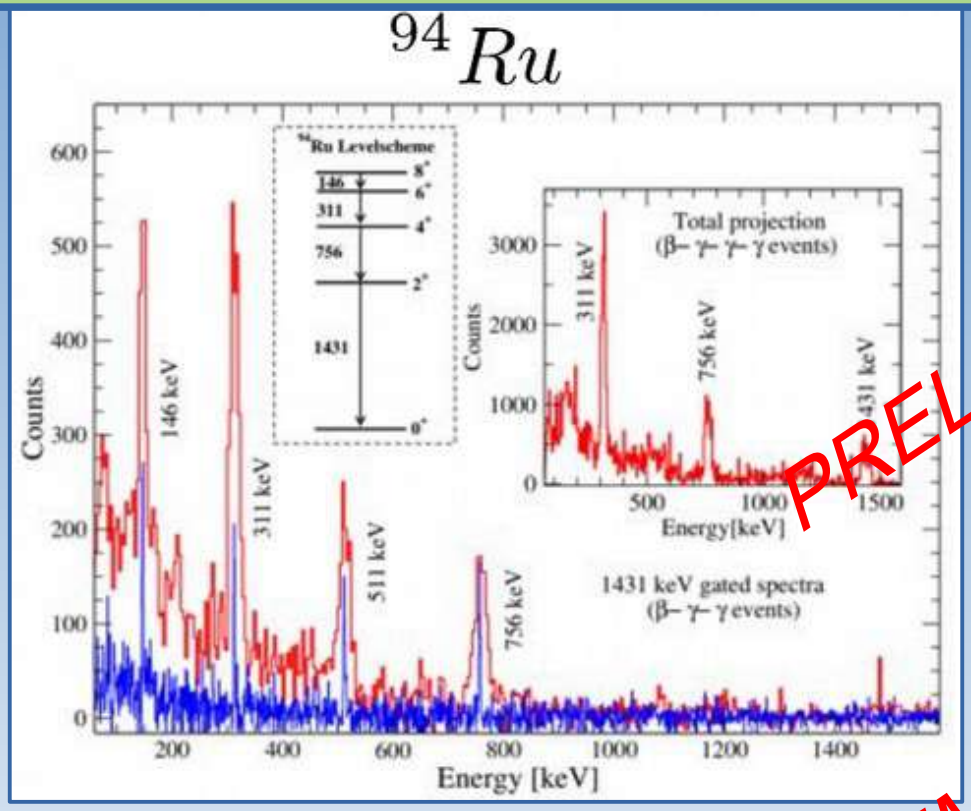


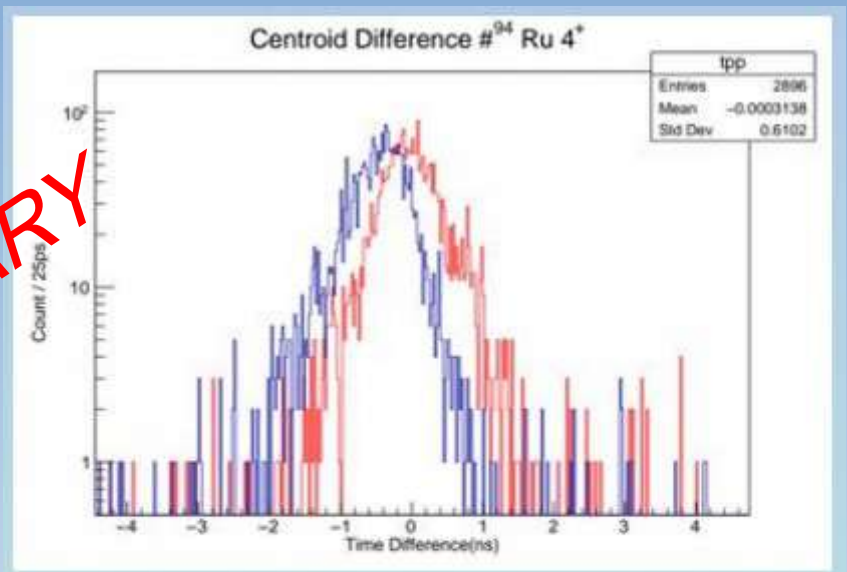
T.S. Brock *et al.*, PRC **82**, 061309(R) (2010)

S. Jazrawi (Surrey)

Physics commissioning experiment S480

- ^{95}Pd: β-delayed γs (^{95}Rh) and β-p-γs (^{94}Ru)

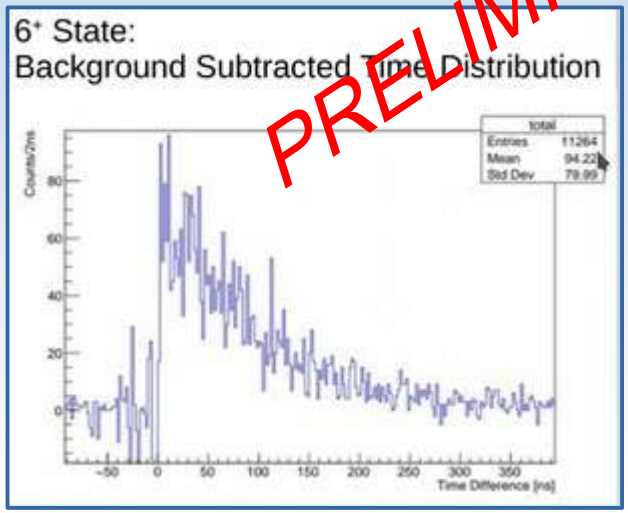




PRELIMINARY

PRELIMINARY

$$\tau(4^+) = 32(11)ps$$



$$T_{1/2}(6^+) = 63(3)ns$$

Reported Value

H. Mach et. al., Phys. Rev. C. 95, 014-313 (2017)

$$T_{1/2}(6^+) = 65(2)ns$$

Remote and Virtual Access

- Development of Remote Access capabilities for DESPEC experiments

Detector Health

Environmental variables

Live Scalers

LN2 filling

DAQ monitoring

DAQ control

Data processing

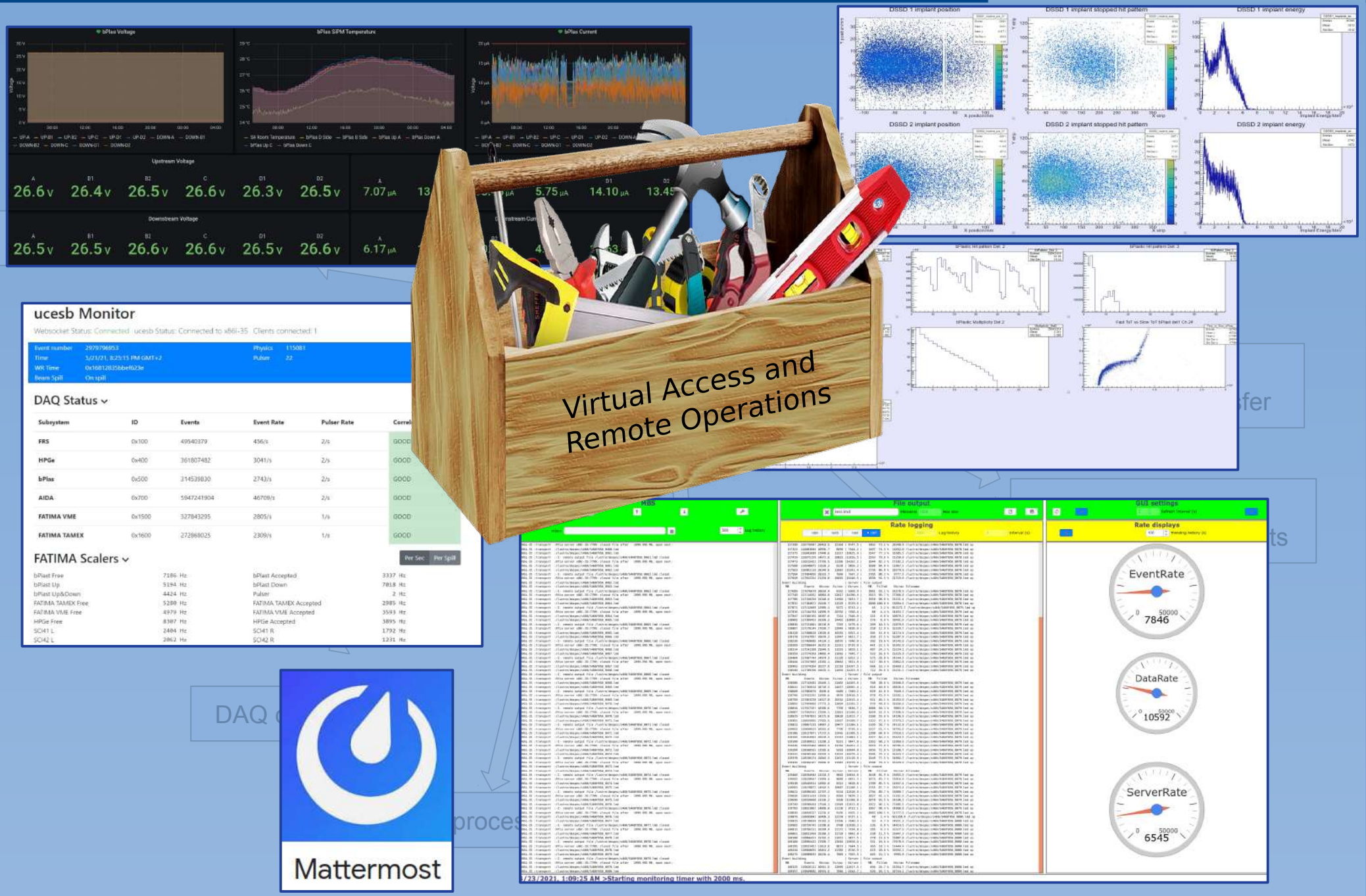
Data visualisation

Cameras and microphones

Procedural and Organisational aspects

Training and knowledge transfer

Remote and Virtual Access



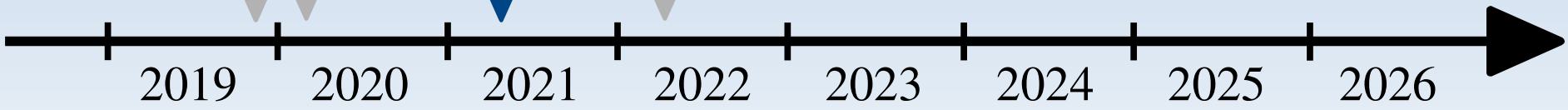
DESPEC Overview: physics goals, setup, subsystems

Engineering run **d002** in late 2019

Physics commissioning: experiment **S480**

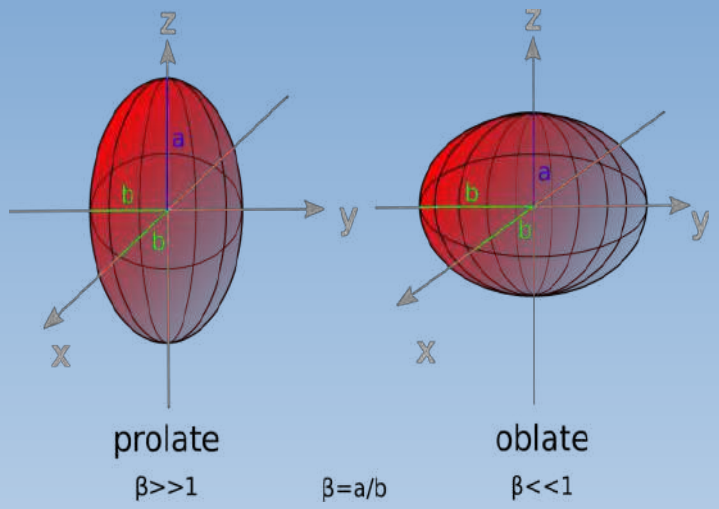
Experimental campaign 2021 **(S452, S460, S496)**

Upcoming campaign 2022 **(S450, S505)**



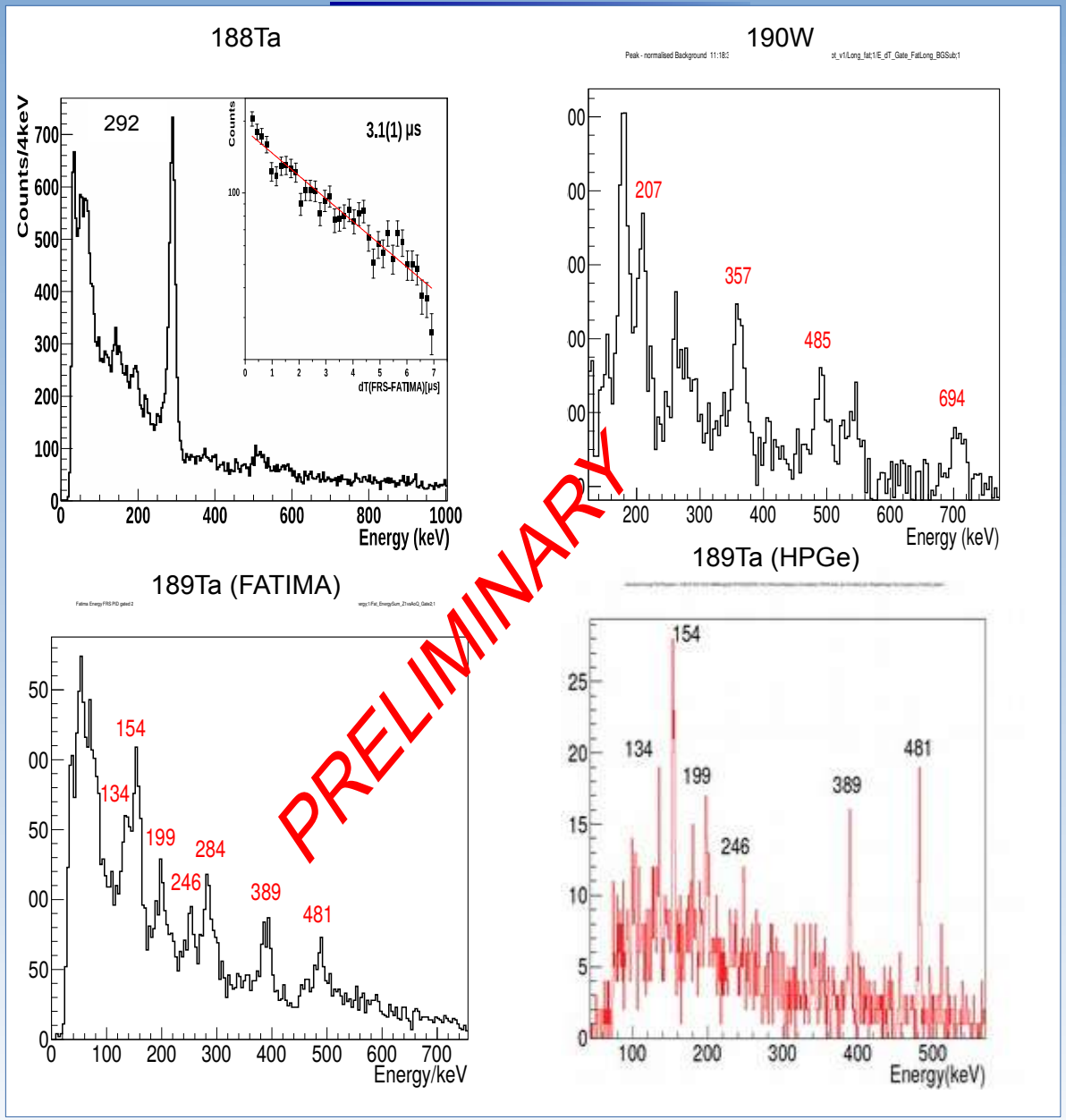
Plans for 2023→ 2024 and beyond

S452: prolate-oblate transition at A~190



- **Fast-timing measurements, isomer decays, γ spectroscopy**
- Produce n-rich Ta, Re, Hf, W isotopes: ^{208}Pb on ^{9}Be
- Ions implanted into AIDA, event-by-event PID → FRS
- β-decay times with fast plastic scintillators
- β-delayed γ deexcitation with FATIMA
- Ge-detectors for high-resolution "monitoring" & isomer spectroscopy

B(E2;$2^+_1 \rightarrow 0^+_1$) of ^{196}Os, $^{188\text{-}192}$W, level energies in ^{188}Hf



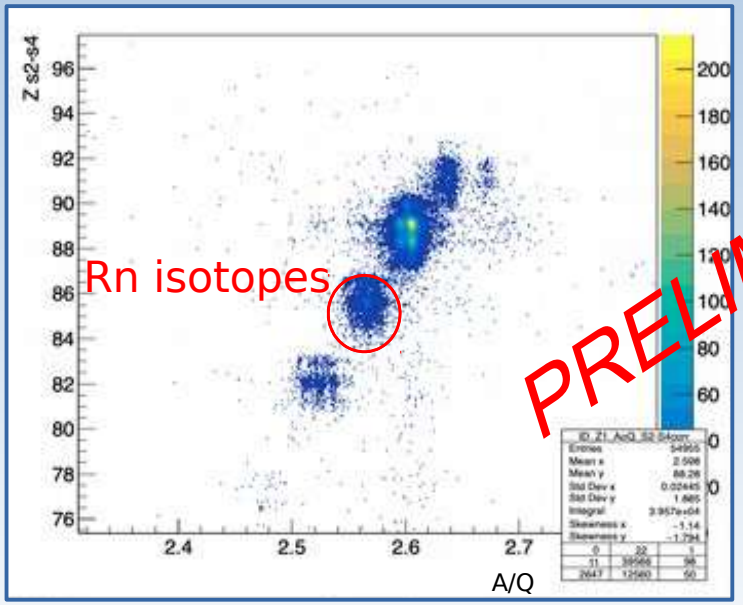
E. Sahin, P. Koseoglou, S. Alhomaidhi (TU Darmstadt)

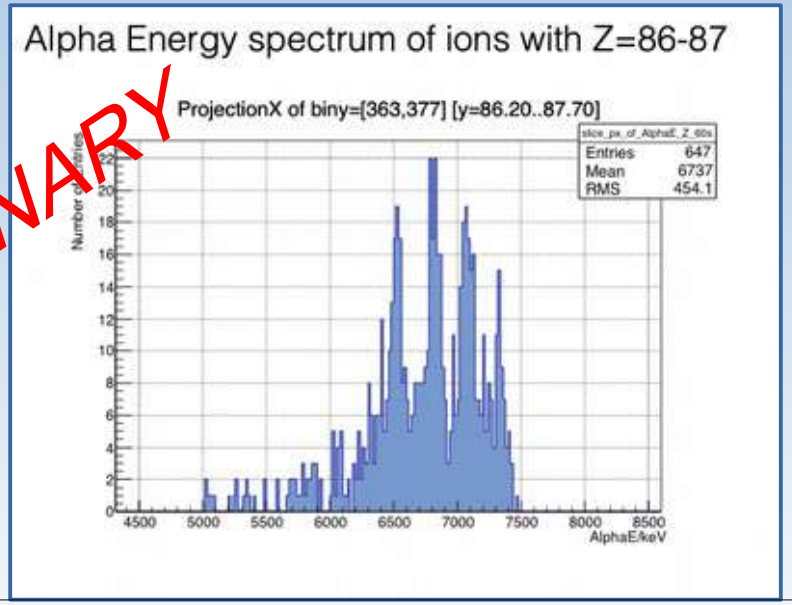
S460: Po-Fr nuclei south-east of the A~225 island of octupole deformation

- Rn-Th (Z=88-90) actinide nuclei around mass number A~225: strong octupole correlations
- Lack of experimental information

- Fragmentation of ^{238}U on ^{9}Be
- Intermediate setting to confirm PID:

^{218,219}Rn: first time the DESPEC setup was used to measure **alpha decay!**



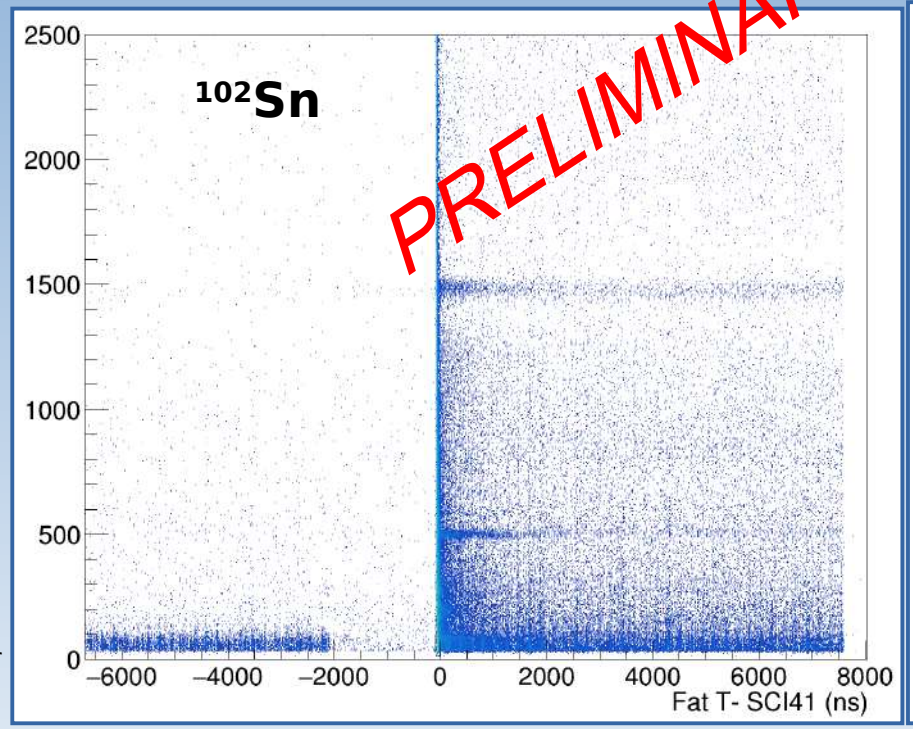


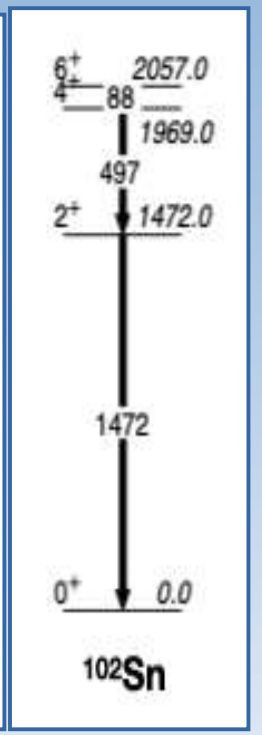
N. Hubbard (TU Darmstadt), H.M. Albers (GSI)

M. Polettini (Uni. Milano)

S496: Core breaking in neutron-deficient Sn isotopes

- Assessing core-breaking contribution in the neutron-deficient Sn isotopes by measuring lifetimes of: (a) first 4^+ state in ^{102}Sn, (b) $(7/2^+)$ state in ^{103}Sn
- First experiment with the 'wide' AIDA + βPlast geometry





(a) γ-γ time difference measurement following the isomeric decay from 6+ state with $T_{1/2}$=367(11) ns

(b) α-γ time difference measurement following the alpha decay from g.s of ^{107}Te with $T_{1/2}$=3.1(1) ms

G. Zhang, INFN Legnaro

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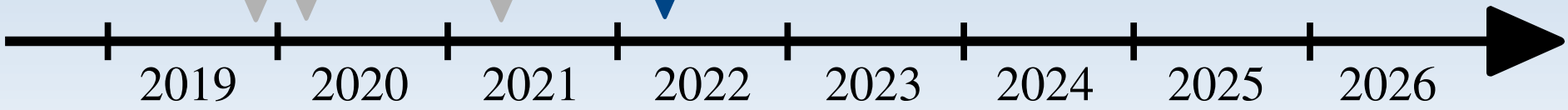


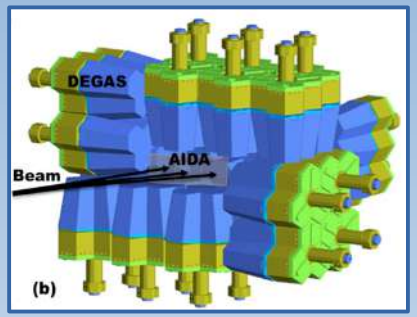
Plans for 2023→ 2024 and beyond

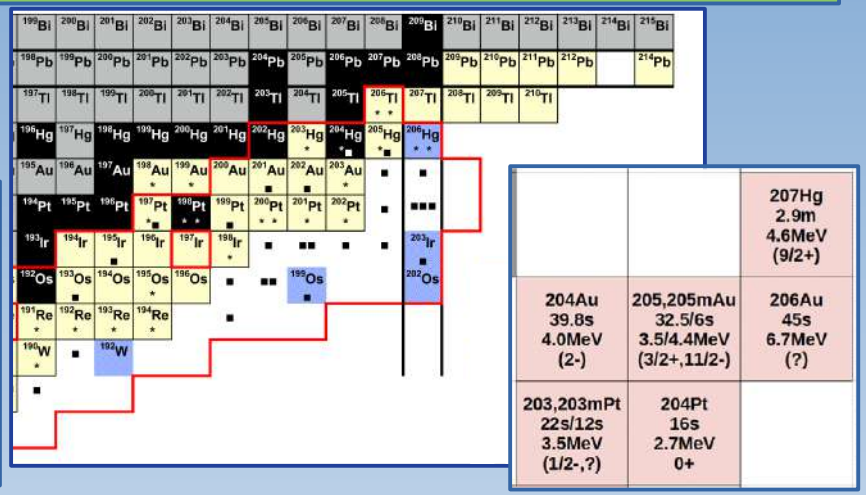
Experimental Campaign Spring 2022

S450: Study of N=126 nuclei: Isomeric and beta decays in ^{202}Os and ^{203}Ir (Podolyák)

Structure of N=126,125 nuclei (^{203}Ir, ^{202}Os, ^{203}Pt, ^{202}Ir) gives info about individual orbitals
=> improved predictions for r-process path

Method: βγ-Spectroscopy
Instruments: 'wide' AIDA, DEGAS
SIS18 beam: ^{208}Pb at 1 GeV/u
Granted beamtime: 18 shifts

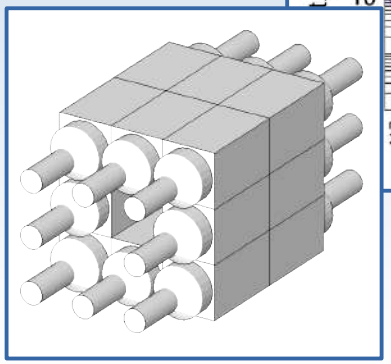


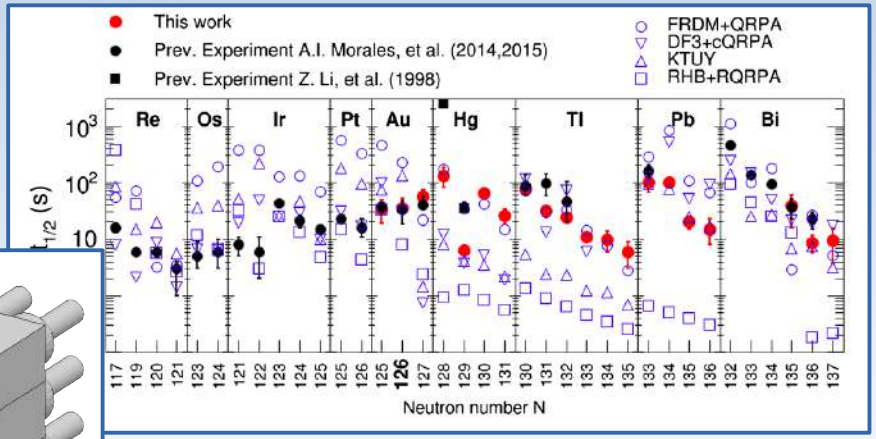


S505: Investigation of the beta-strength crossing N=126 and the formation of the 3rd r-process abundance peak (Tain, Morales, Nacher)

Large discrepancies, no model consistent with data across N=126
$T_{1/2}$ is not unequivocally related to β strength: need for measurement

Method: Total Absorption Spectrometry
Instruments: 'narrow' AIDA + DTAS
SIS18 beam: ^{208}Pb at 1 GeV/u
Granted beamtime: 20 shifts





Courtesy of G. Benzoni

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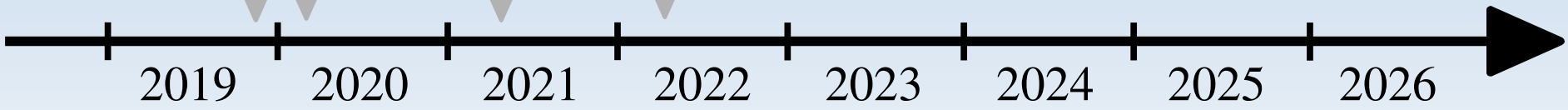


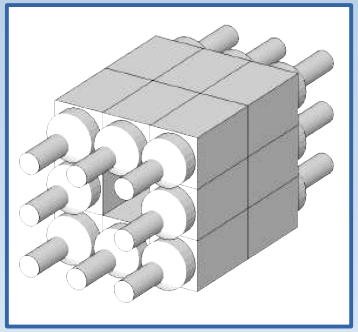
Plans for 2023→ 2024 and beyond

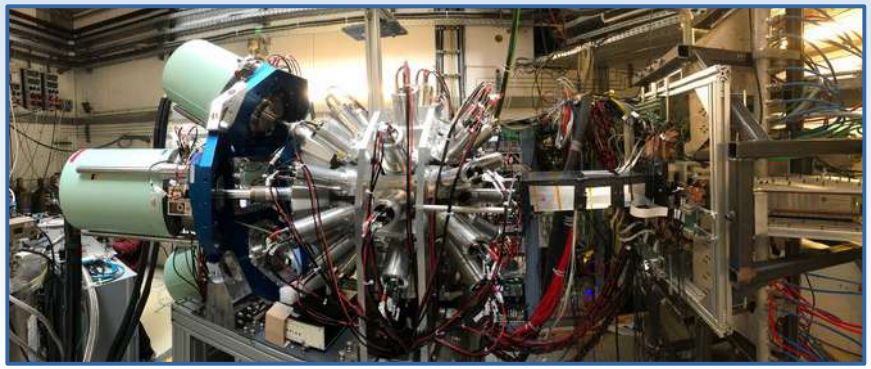
2023-2024 and 2025+

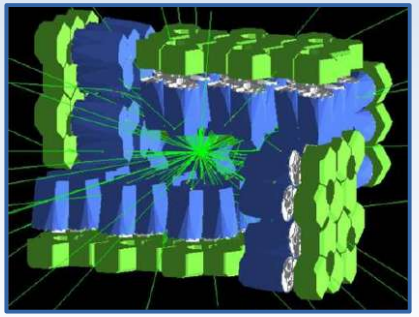
- In 2023-2024, DESPEC collaboration will exploit **high-resolution (DEGAS/FATIMA), high-efficiency studies (DTAS) and exclusive measurements (BELEN)**
- Improvements to detectors, DAQ, analysis framework
- One setup per year to minimize changes and reduce commissioning time
- Dedicated campaigns for each setup

Timeline:

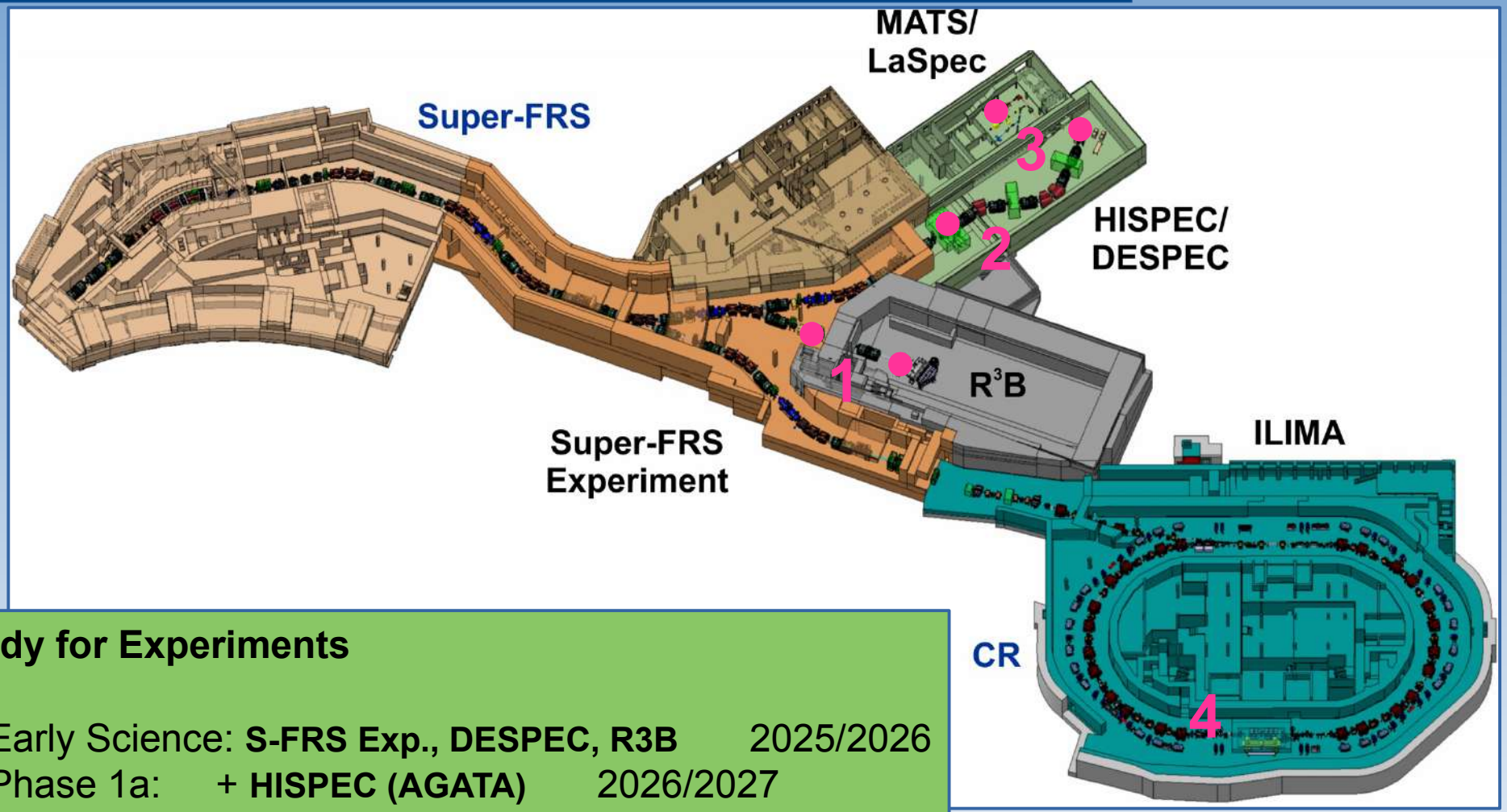
- Workshop on future experiments ***Jan 2022***
- LOIs discussed by HISPEC/DESPEC management board ***Mar 2022***
- Proposal submittion to management board ***Spring 2022***
- Proposal submission to G-PAC ***Summer 2022***







Physics startup at the FAIR facility



Ready for Experiments

1	Early Science:	**S-FRS Exp., DESPEC, R3B**	2025/2026
2	Phase 1a:	+ **HISPEC (AGATA)**	2026/2027
3	Phase 1b(α):	+ **MATS/LASPEC**	2027
4	Phase 1b(β):	+ **ILIMA**	2027

1 with SIS18 beams, 2 preferably SIS100 operation,
3 SIS100 operation needed

DESPEC
Plan to move DEGAS(+FATIMA) set-up from FRS/S4 to Super-FRS starting in Q1 2025 after the phase-0 runs of 2024

Courtesy of J. Gerl

Summary and Acknowledgements

- **Successful commissioning** of the DESPEC setup at GSI
- Experimental campaigns in **2020 and 2021** (physics results soon!)
- Experiments with **DTAS (S505)** and **DEGAS (S450)** planned for 2022
- Strategy for **2023-2024 beamtime**
- Future plans **early physics with DESPEC at FAIR** 2025+

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...and many more from the **DESPEC Collaboration** and the **FRS Group**

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Thank you for your attention!