IDS Collaboration

KU LEUVEN

AARHUS UNIVERSITET

JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

Universität zu Köln

INFN Istituto Nazionale di Fisica Nucleare

UNIVERSITY OF WARSAW

IFIN-HH

NRF iThemba LABS

UNIVERSITY of the WESTERN CAPE

UNIVERSIDAD COMPLUTENSE MADRID

CSIC

IFIC INSTITUT DE FISICA CORPUSCULAR

LUND UNIVERSITY

UNIVERSITY of York

Science & Technology Facilities Council

UNIVERSITY OF SURREY

UNIVERSITY OF LIVERPOOL

THE UNIVERSITY OF TENNESSEE KNOXVILLE

ISOLDE Decay Station

ISOLDE Workshop and Users meeting 2022

November 30, 2022 to December 2, 2022

New results from the ISOLDE Decay Station

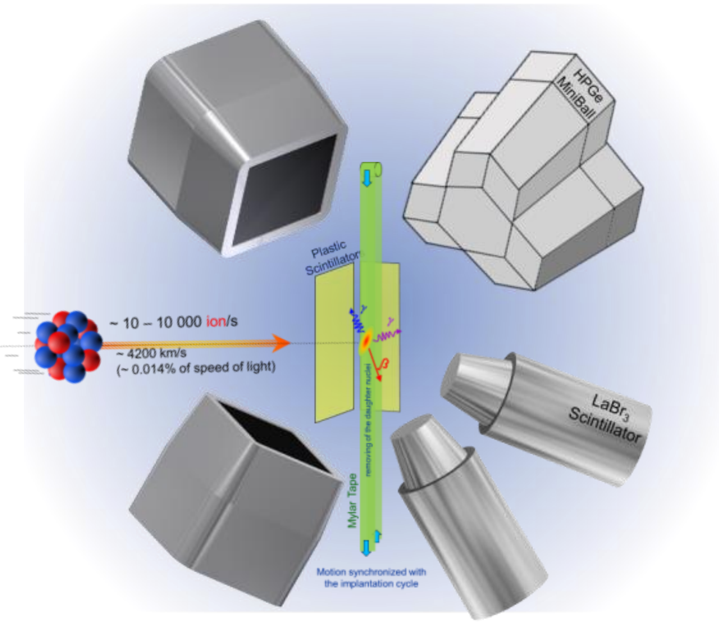
Razvan LICA, PhD (IFIN-HH, Romania)

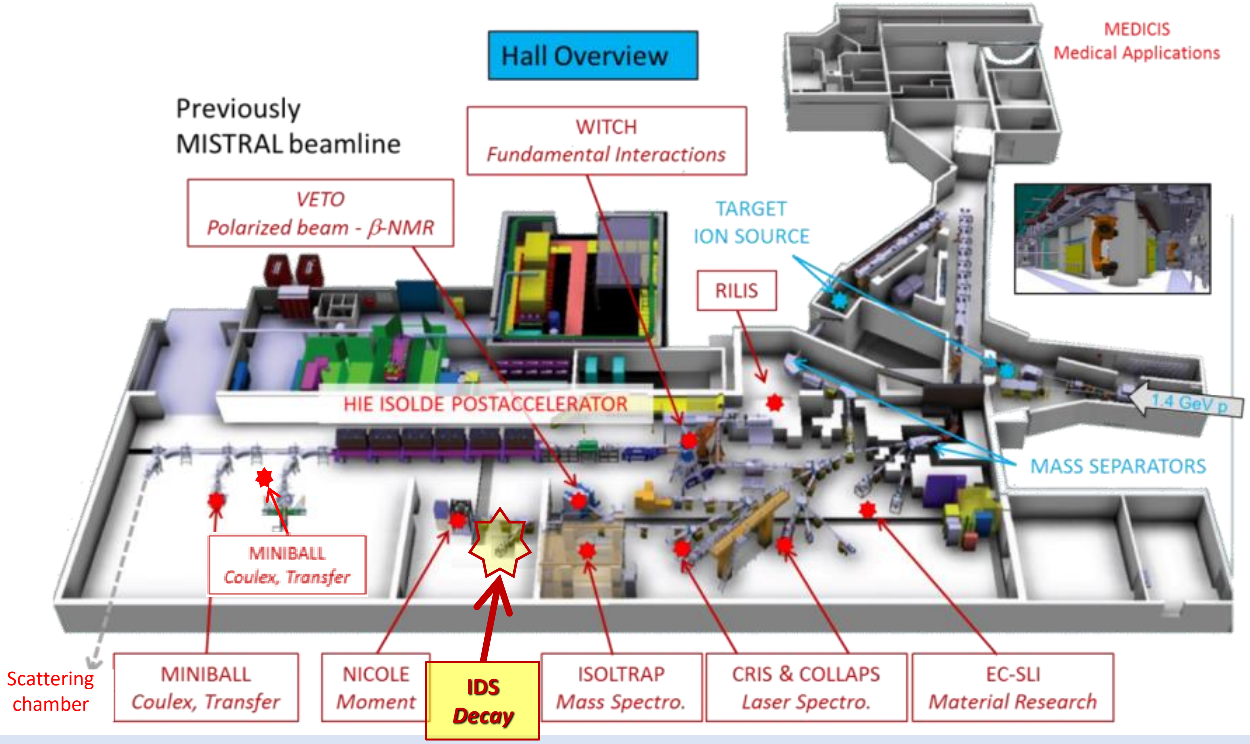
IDS Collaboration Spokesperson

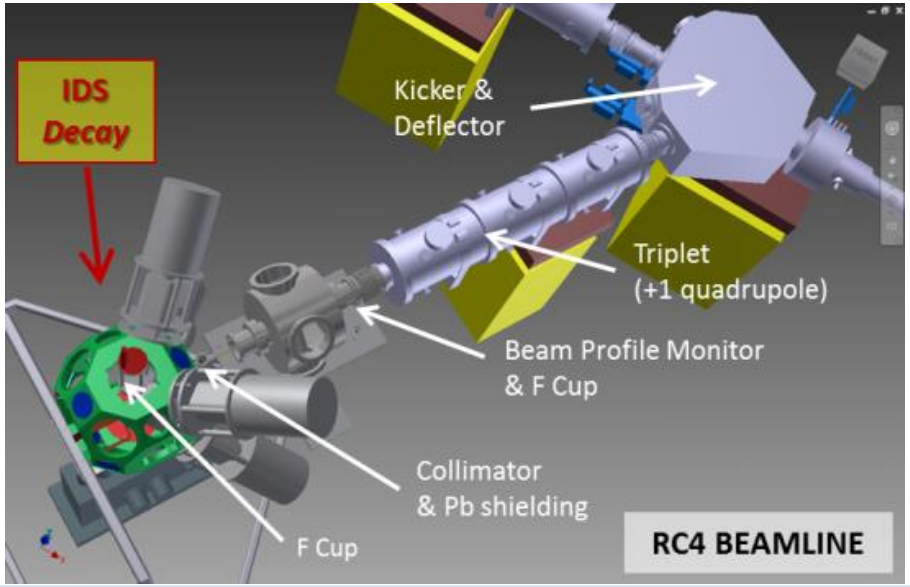
- Overview
- Experimental arrangements
  - Neutron spectroscopy
  - Particle spectroscopy
  - High beta-gamma efficiency
  - Fast-timing studies
  - Conversion electron spectroscopy
- Previous experiments and publications
- New experimental campaign (2021-2022)
- Future developments
  - Support structure
  - Neutron spectroscopy
  - Extra HPGe detectors
  - TDPAC, Decay chambers
- Conclusions

The ISOLDE Decay Station (IDS) project aims to provide:

- **Permanent Setup** for beta-decay studies using the beams from ISOLDE (since 2014)
- **Flexible approach** (for several decay types and studies)
  - **HPGe detectors** (4 permanent Clovers + extra)
  - **Ancillary detectors** ($LaBr_3$, plastic scintillator, silicon, neutron)
  - **Tape station**
  - **In-Source Laser Spectroscopy Studies using RILIS** (since 2017)
- **Collaboration** to support and perform decay studies at ISOLDE





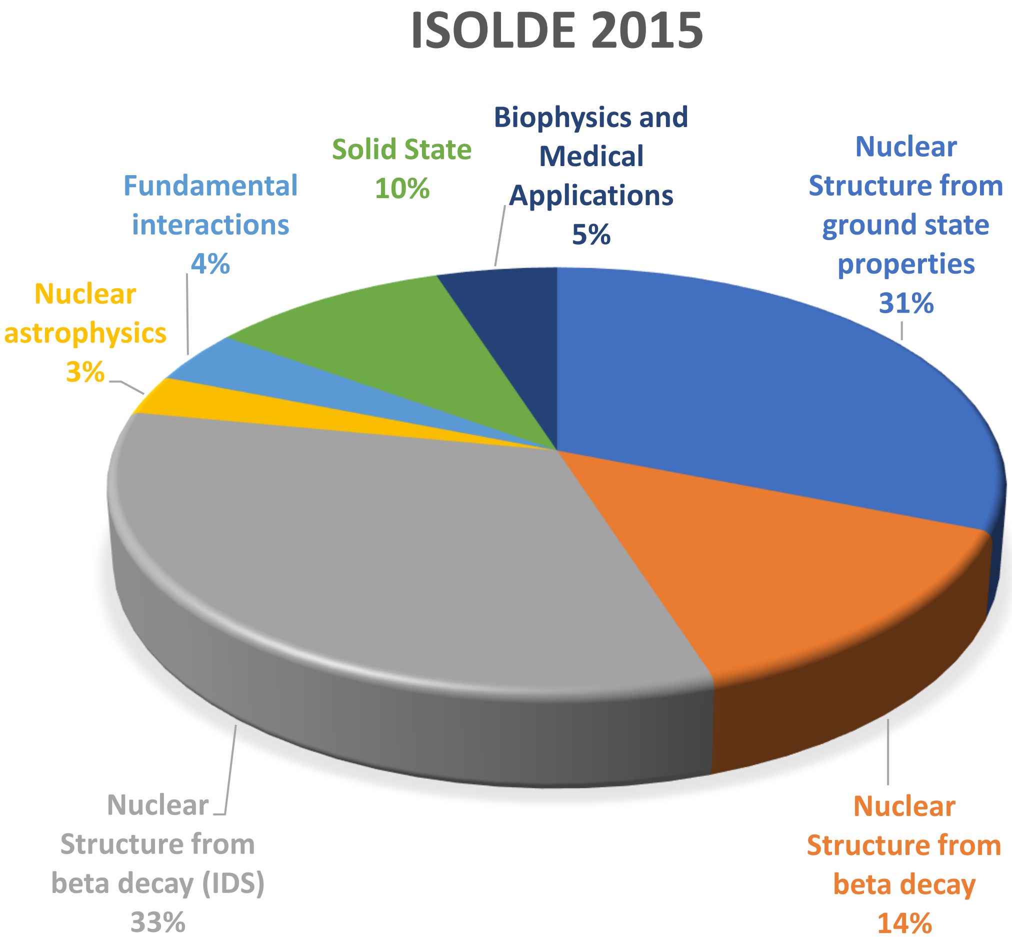


Collaborating institutes

- Belgium (KU Leuven)
- Denmark (Aarhus University, Department of Physics and Astronomy)
- Finland (University of Jyväskylä)
- Germany (Institut für Kernphysik - Universität zu Köln)
- Italy (Università degli Studi e INFN Milano)
- Poland (Faculty of Physics, University of Warsaw)
- Romania (IFIN-HH Bucharest)
- South Africa (iThemba LABS)
- Spain (IEM-CSIC Madrid; IFIC-CSIC Valencia; UCM Madrid)
- Sweden (Lund University)
- Switzerland (CERN - ISOLDE)
- UK (STFC Daresbury Laboratory; University of Liverpool; University of York; University of Surrey)
- USA (University of Tennessee)

IDS is supported by 18 institutes across the world, and used by many more globally.

First installation in 2014

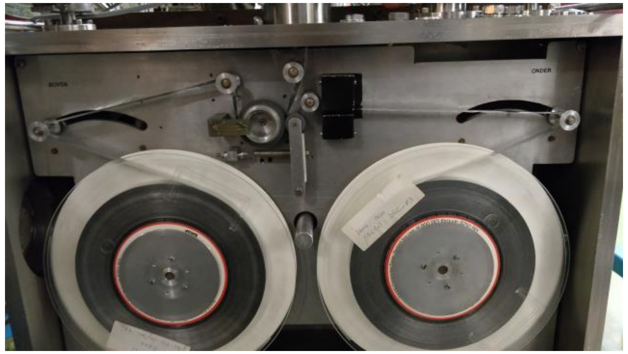


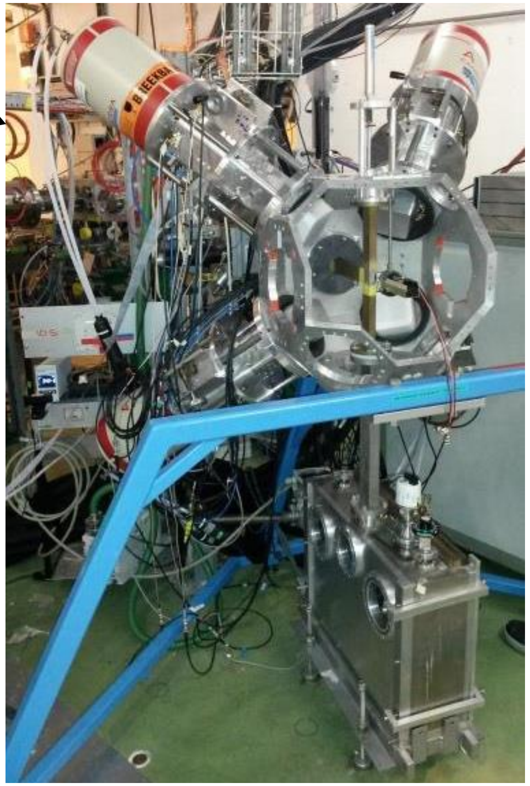
IDS in 2015

Core configuration of IDS (2014 – 2018)

4 HPGe clover detectors (IFIN-HH + KU Leuven)
- 4 clovers with 4 crystals
- Two thin-window detectors
- 20% relative efficiency per crystal
- 120% relative efficiency with addback

Tape station (KU Leuven)
- Aluminized mylar tape
- Fully automated system
- Can be integrated with ISOLDE



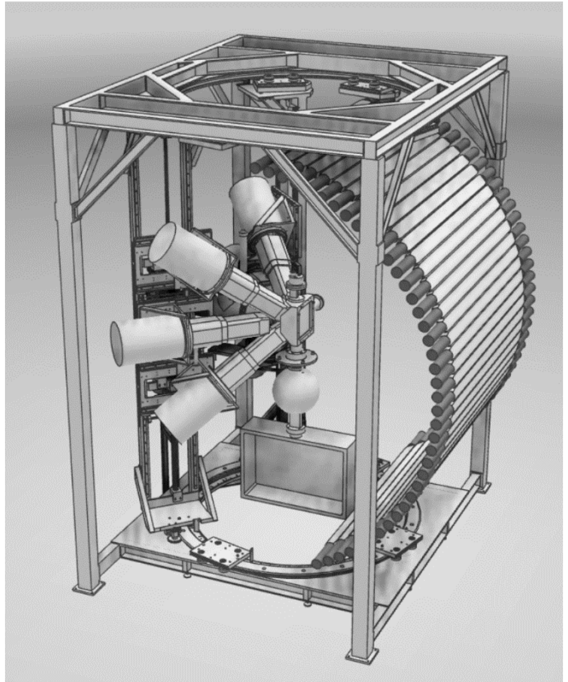


Digital DAQ
NUTAQ VHS-ADC (STFC, JYFL)
- 3 x 16 channels, 100 MHz, 14-bit ADC (virtex4 FPGA)
- MIDAS acquisition software

IDS Upgrades during CERN LS2 (2019 – 2021)

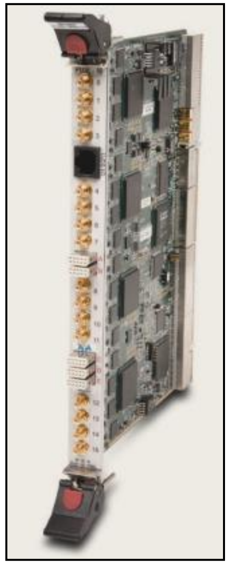
New Support structure

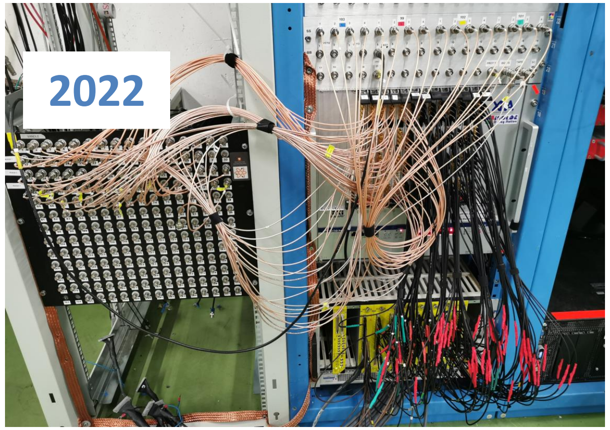
- 2021: finalized the design
- December 2022: installation



New DAQ

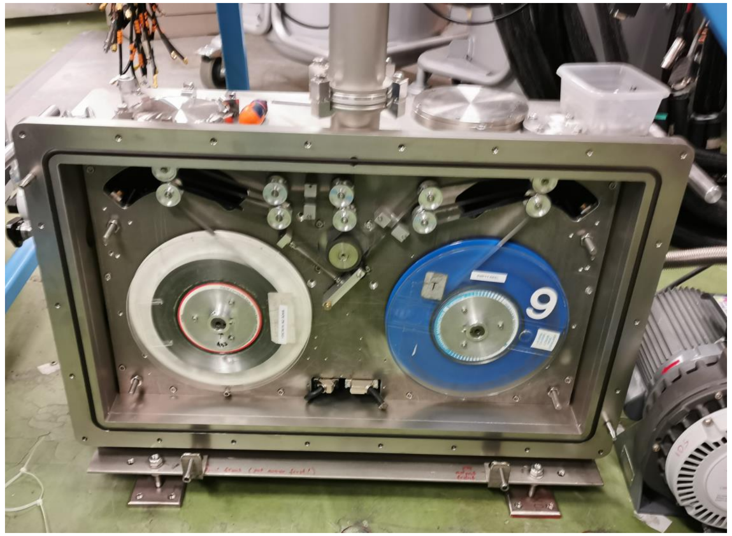
XIA PIXIE-16, 250 MHz, 12-16 bit ADC, 208 ch/crate (13 x 16)



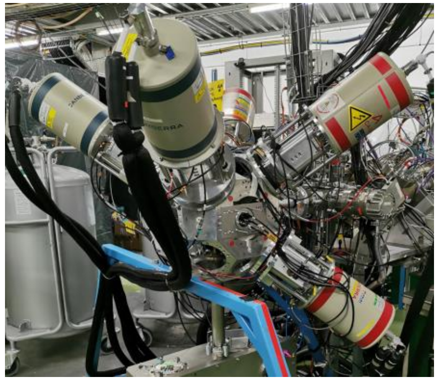


New Tapestation

- 2021: finalized manufacturing
- Jan 2022: installed at IDS

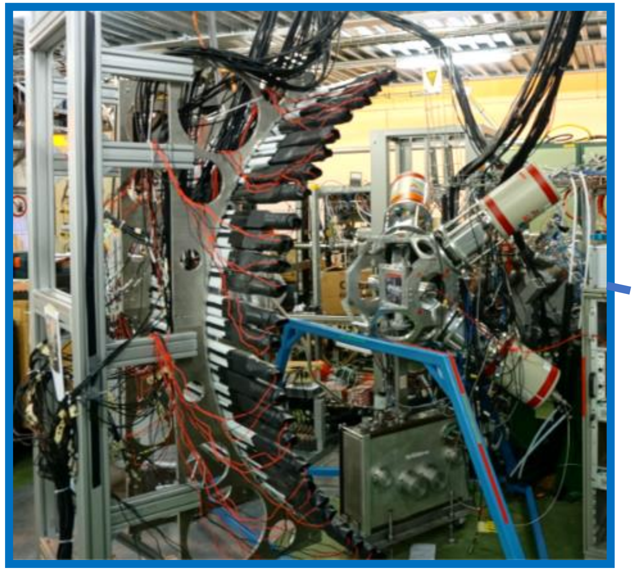


2 new Clover detectors added to the permanent setup

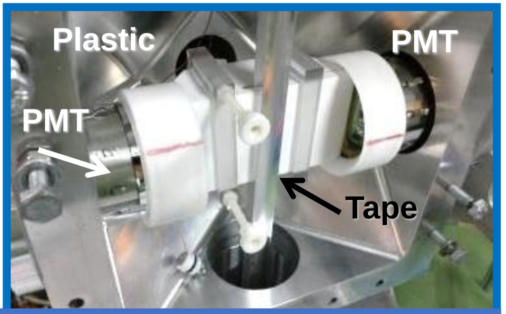


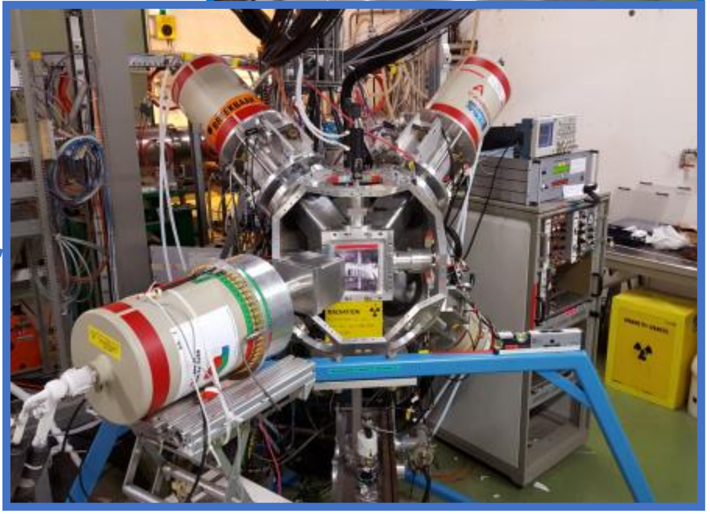
ISOLDE Decay Station 2014-2022

Neutron Spectroscopy

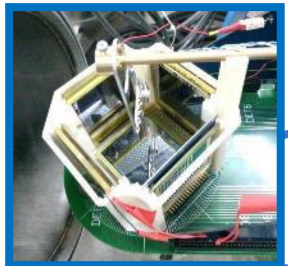


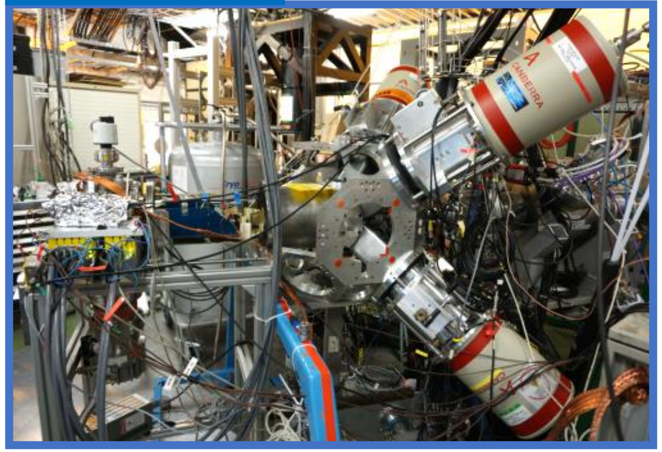
High beta-gamma efficiency



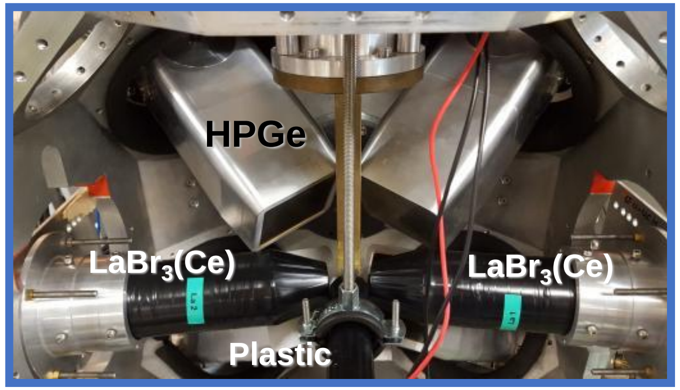


Particle Spectroscopy

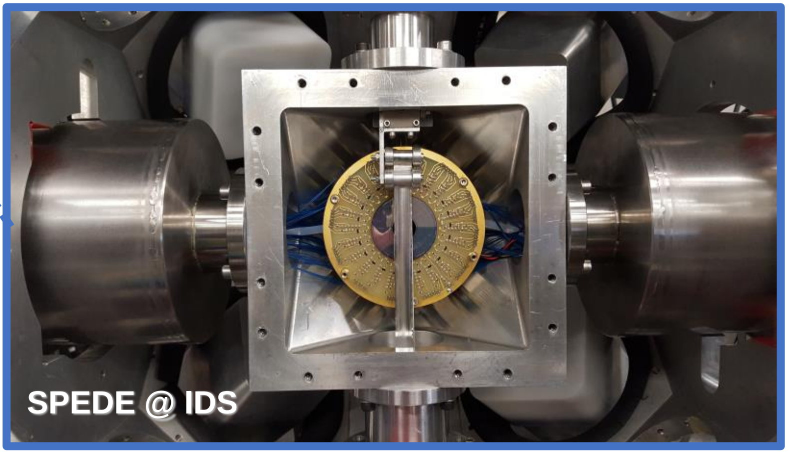




Fast-timing studies



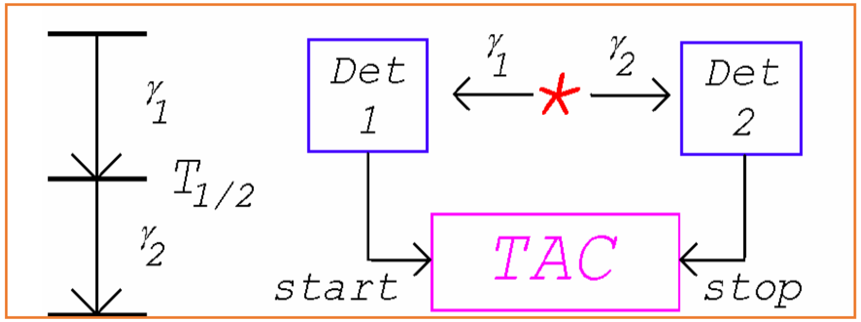
Conversion Electron Spectroscopy

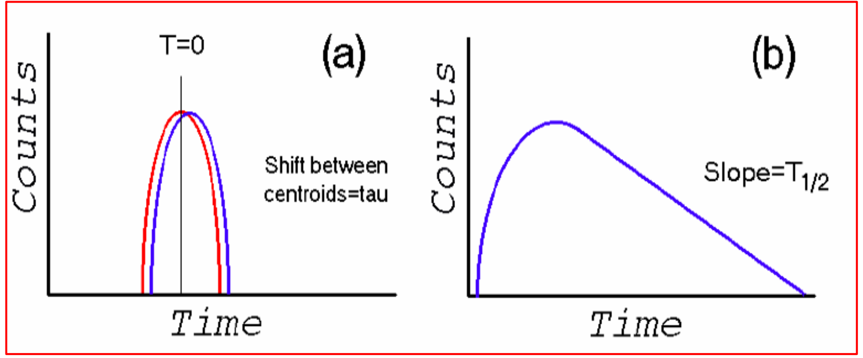


Fast-timing studies

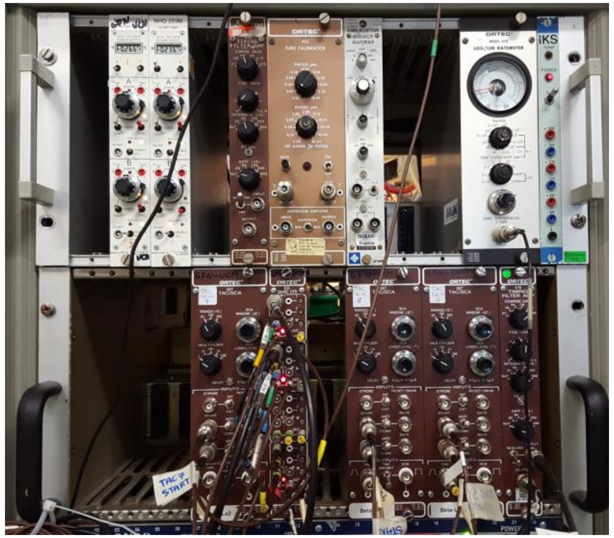
- Well established technique at IDS since 2014 [1,2,3,4, …]
- Detection system comprising of:
  - 4 Clover HPGe - 7% abs. eff. at 500keV
  - 2 $LaBr_3(Ce)$ - 3% abs. eff. at 500keV
  - 1 Plastic Scintillator - 20% abs. eff.

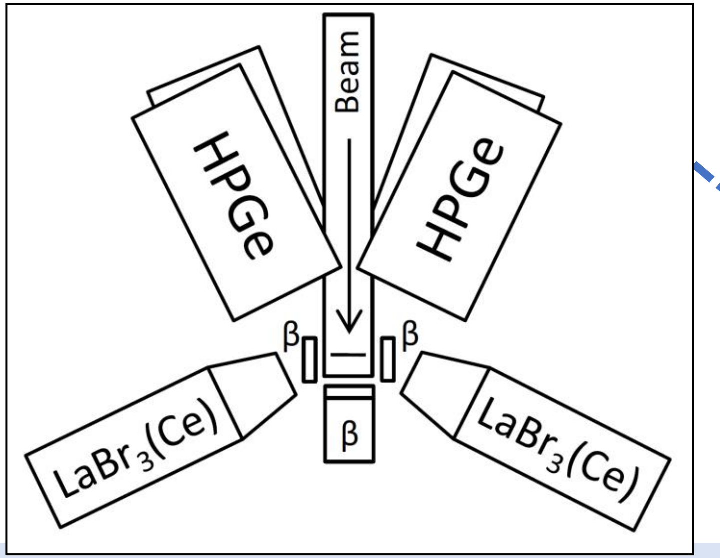
[1] R. Lica et al., Phys. Rev. C 93, 044303 (2016).
[2] R. Lica et al., J. Phys. G 44, 054002 (2017).
[3] L.M. Fraile, J. Phys. G 44, 094004 (2017).
[4] R. Lica et al., Phys. Rev. C 97, 024305 (2018).

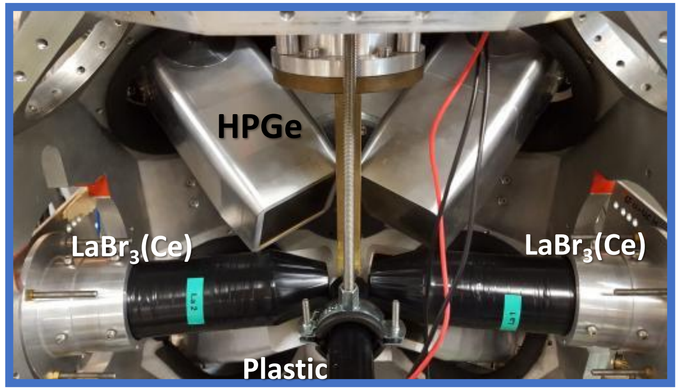




Ranges:
Centroid shift method: - **10 ps - 100 ps**
Slope method - **50 ps - 50 ns** (or longer)
[H. Mach et al. NIM A 280, 49 (1989)]

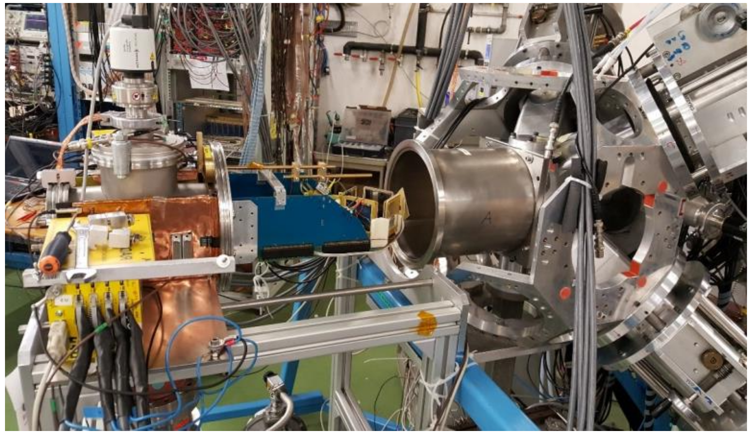


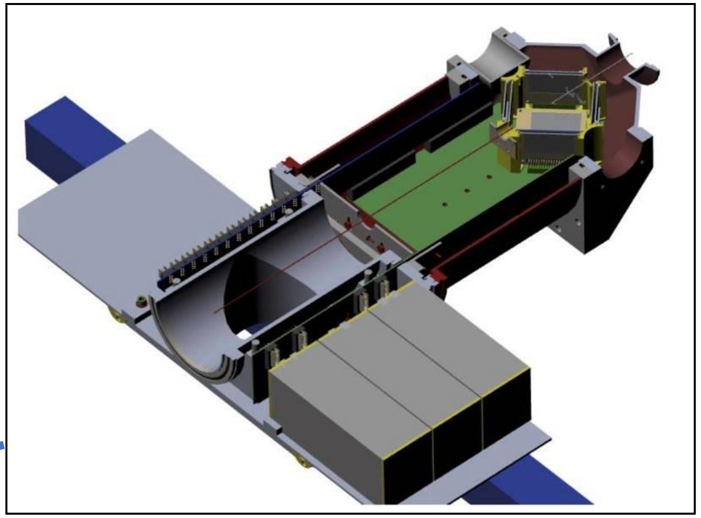


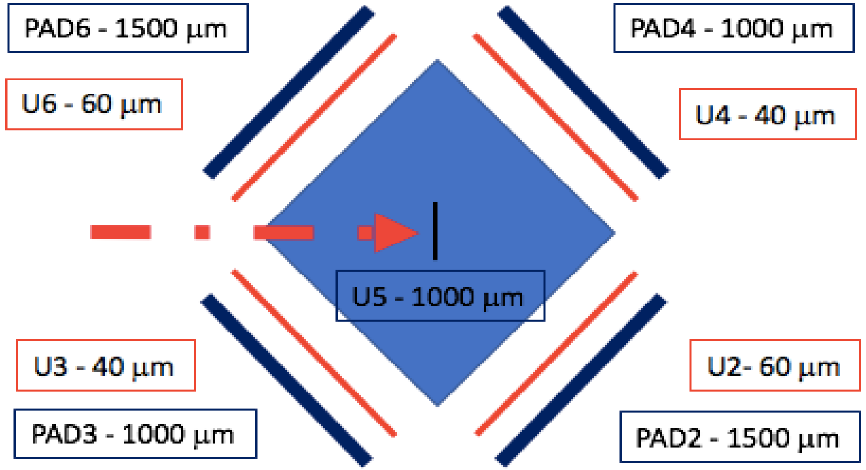


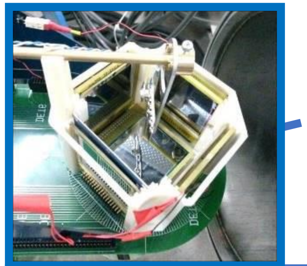
Particle Spectroscopy

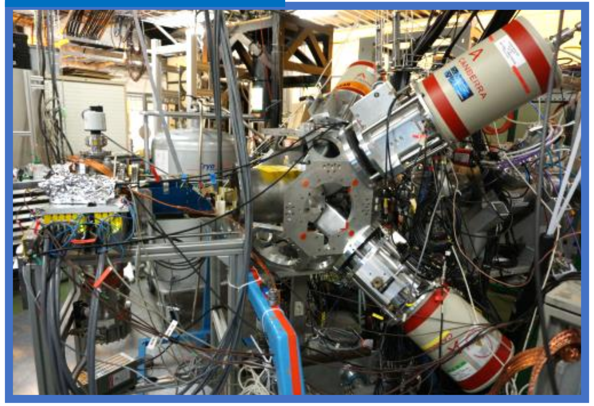
ISOLDE Decay Station + MAGISOL











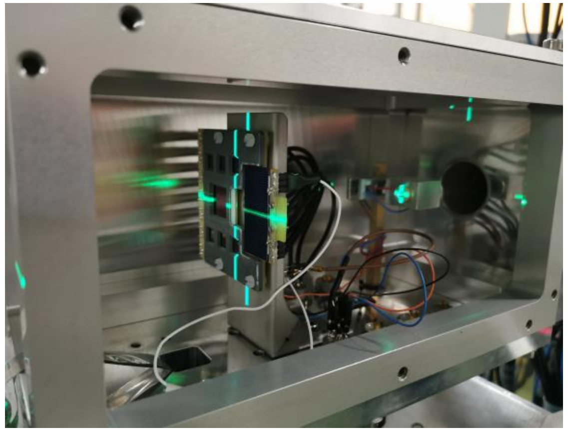
- 4 HPGe Clover detectors + Si box (5 DSSSD's, 4 Pad's)
- Beam implanted on ^{12}C foil or tape

(2014-2018) Using MAGISOL detectors, electronics and DAQ [1]

- 165 ch: **Mesytec** preamplifiers (2xMPR64, 2xMPR32)
- Mesytec STM16+ shapers
- **ISOLDE MBS** and IDS Nutaq use in parallel (synchronized)

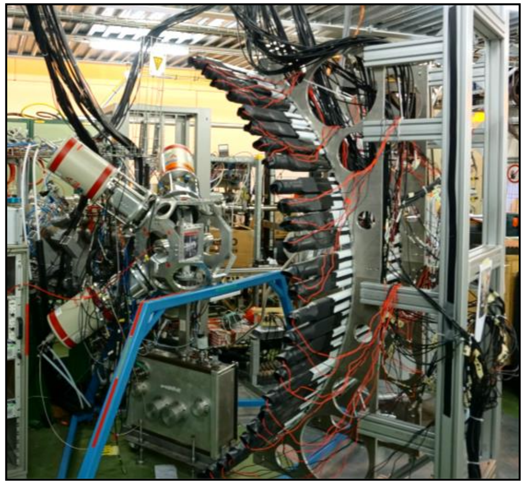
(2021) XIA Pixie-16 handling both particle and gamma detectors

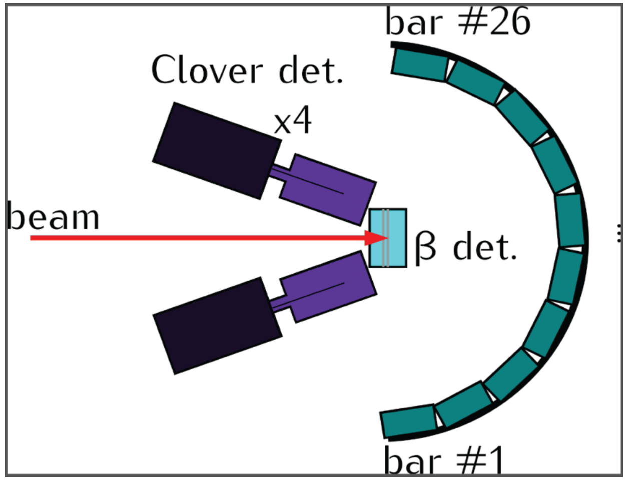
(2021) New cubic chamber employed with SiPIN and Solar Cells (York)



[1] Fynbo, Tengblad, Kirsebom, J. Phys. G: Nucl. Part. Phys. 44 (2017) 044005

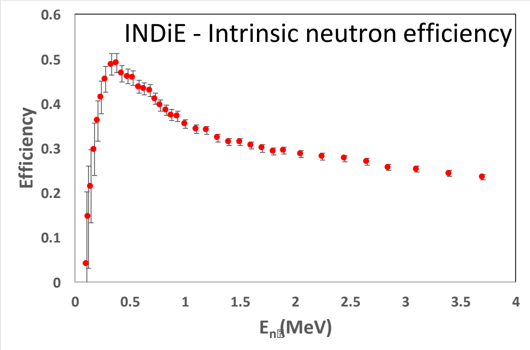
Neutron Spectroscopy at IDS



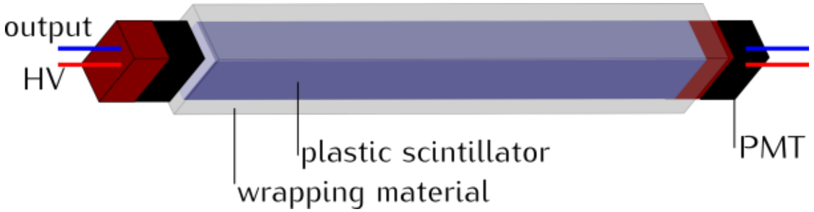


INDiE (IDS Neutron Detector)

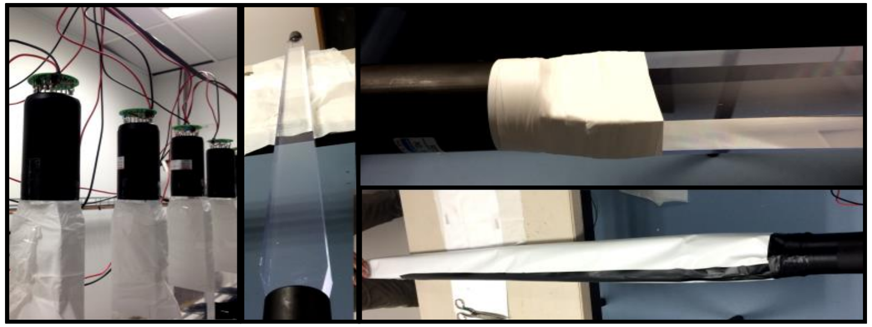
- 26 x 3x6x120 cm^3 bars
- Ω=14.9% of 4π
- Intrinsic neutron efficiency 25%-50%
- ϵ(neutron) = 3.7%-7.5%
- Collect 1000 neutrons / 5 days → 0.14 ions/s (P_n=30%)

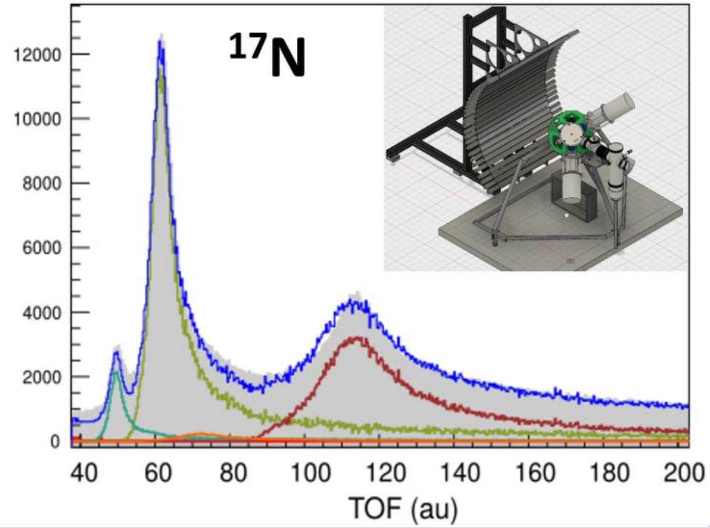


- TOF detector, inspired from the VANDLE medium bar design (UTK, USA)



- Built in 2016 by the IDS local group



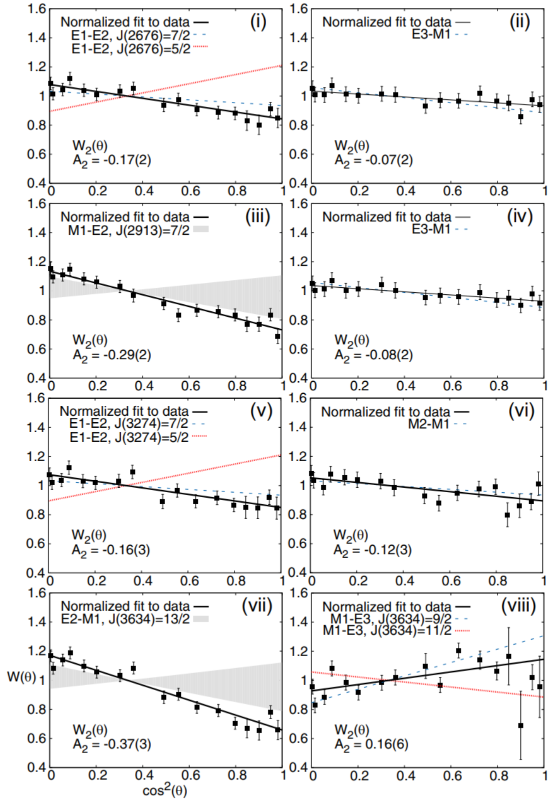


- Nitrogen isotopes available at ISOLDE with CaO target
- GEANT 4 simulation of instrument response
  - Scattering in steel frame/floor
  - Resonance widths from literature

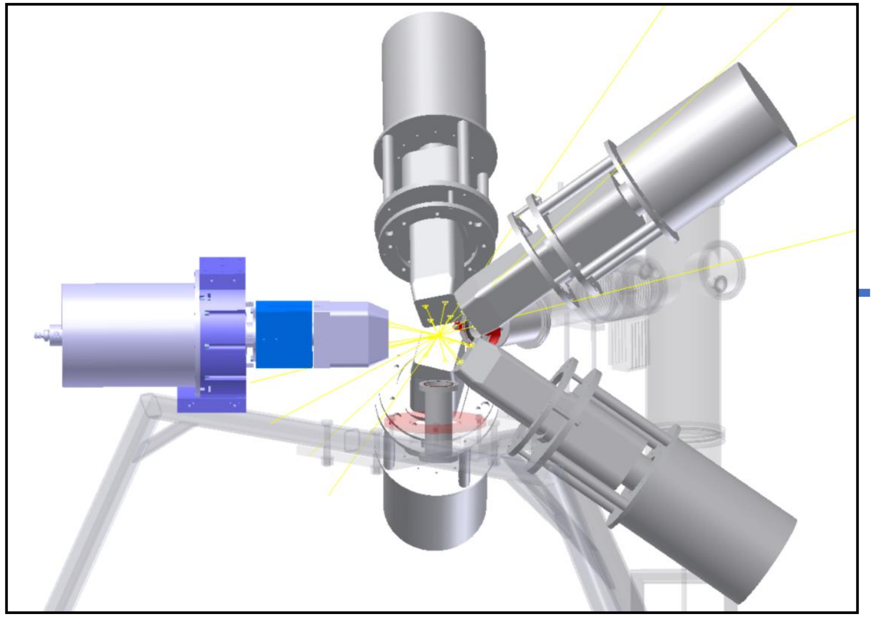
High beta-gamma efficiency

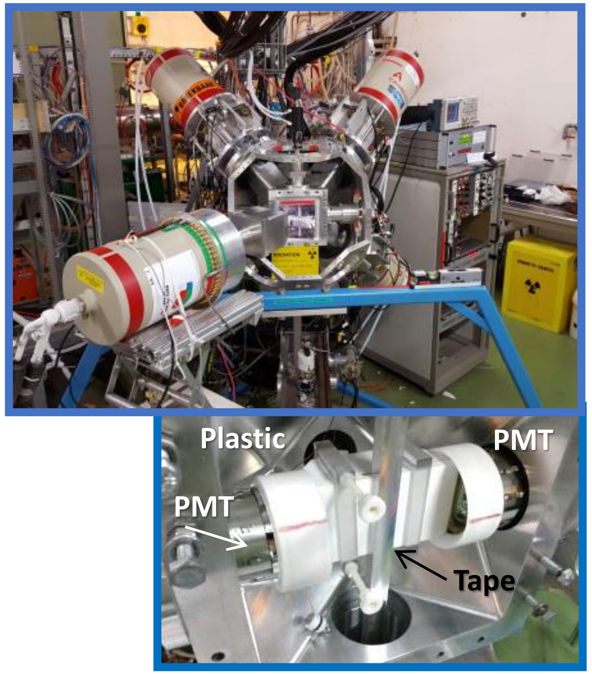
Detection setup

- 5 Clover detectors
- ~4π plastic scintillator around the implantation point
- 5th Clover can be placed at a specific angle to perform **angular correlation studies [1]**.

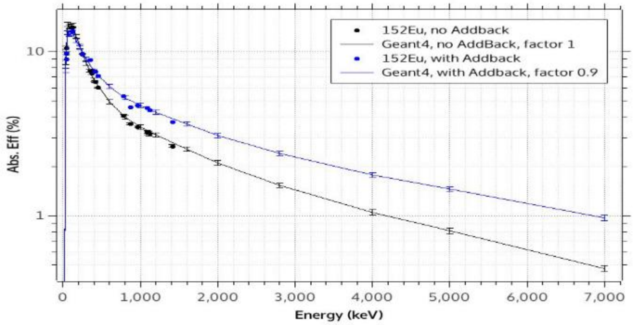


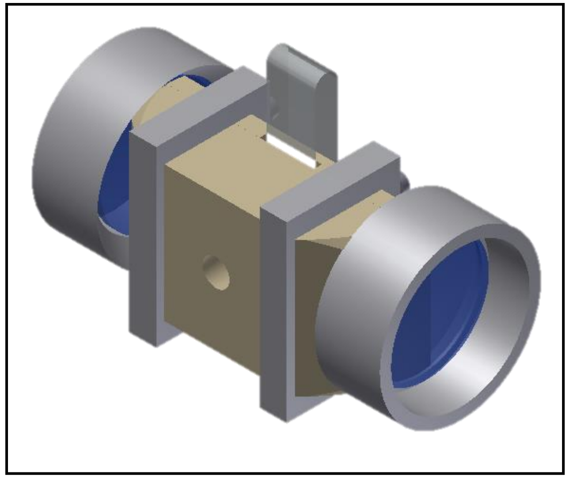
[1] T. A. Berry et al., Phys. Rev. C101, 054311 (2020)



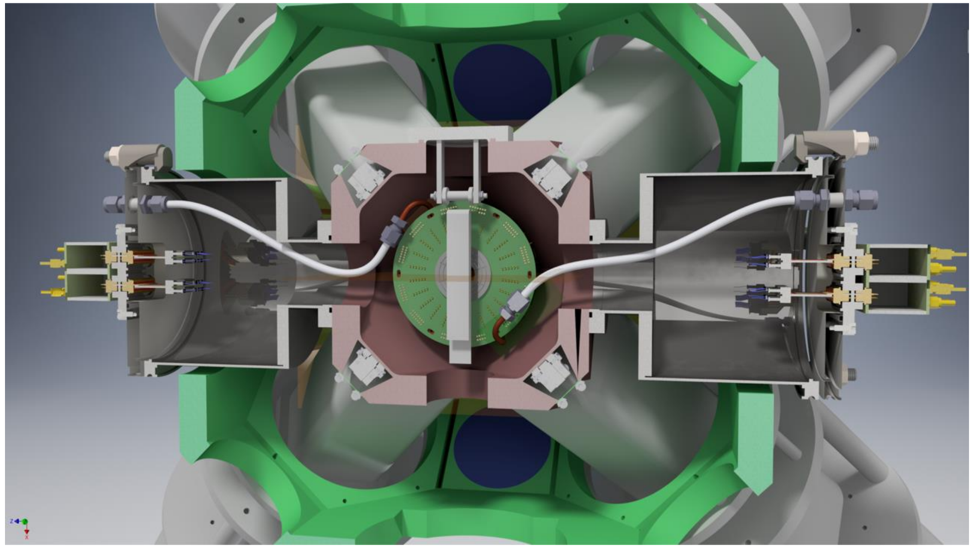


- **Absolute β efficiency - 90(5) %**
  (single/beta gated ratios)
- **Absolute γ efficiency - 4% @1MeV**
  Using GEANT4 to extrapolate





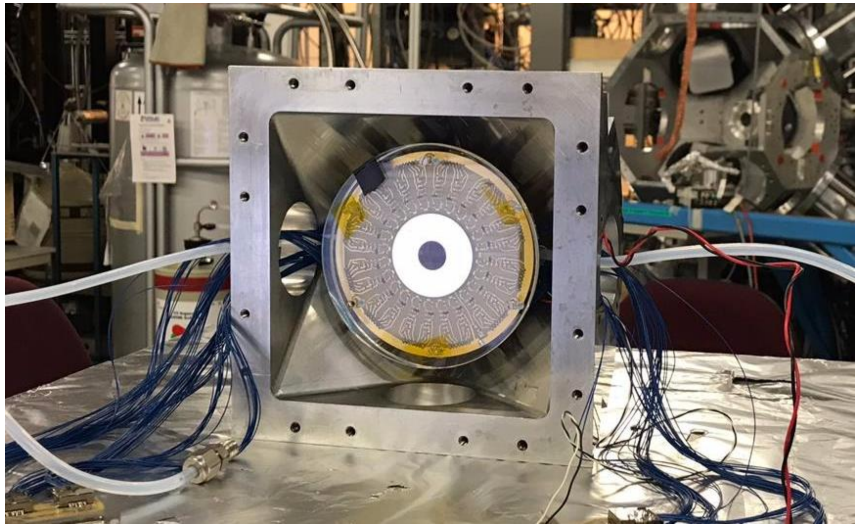
Conversion Electron Spectroscopy

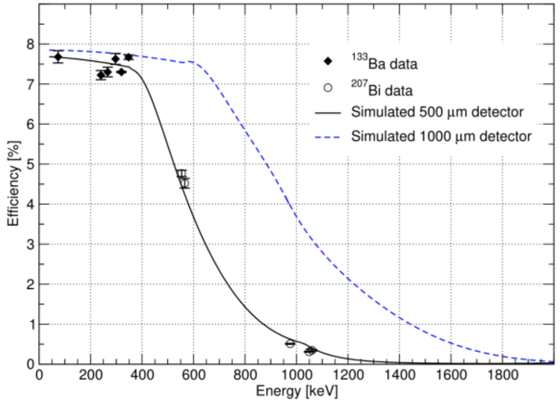


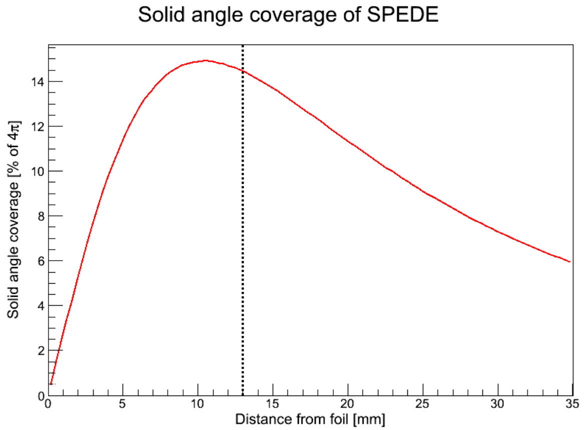
- Annular Si detector with 24 segments.
- Ethanol cooled to -20°C
- FWHM at 320 keV in the region of 6-8 keV.

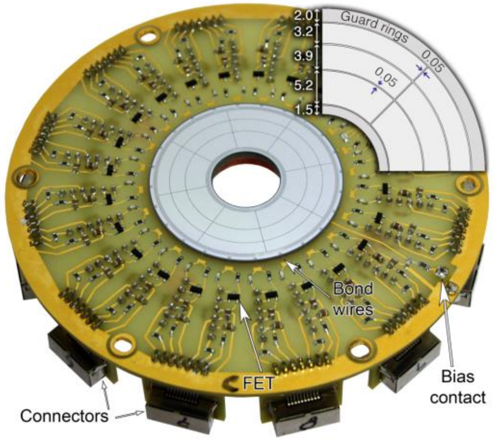
P. Papadakis et al., Eur. Phys. J. A. 54:42, 2018

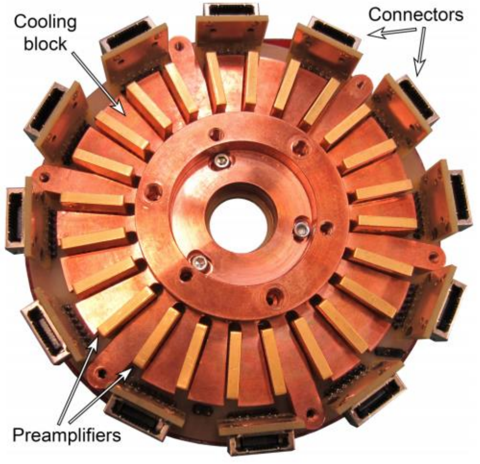
- Had to adapt current IDS setup to accommodate SPEDE detector, electronics and cooling system designed initially for MINIBALL.



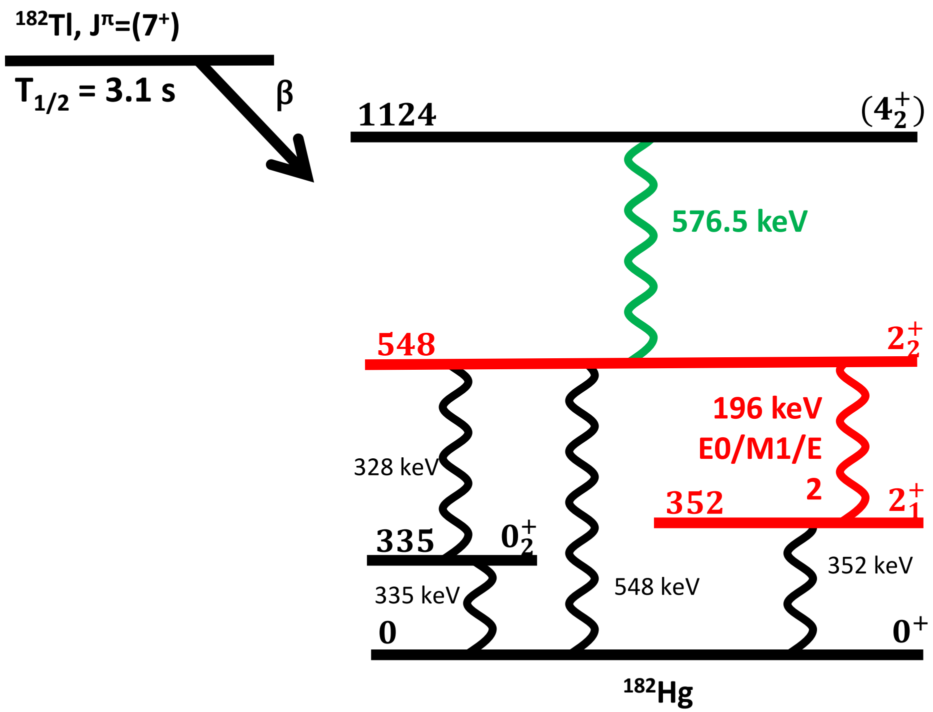








Conversion Electron Spectroscopy

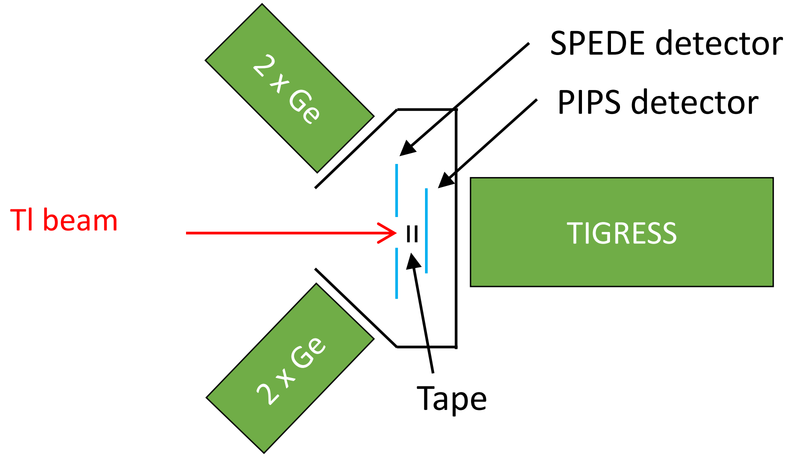


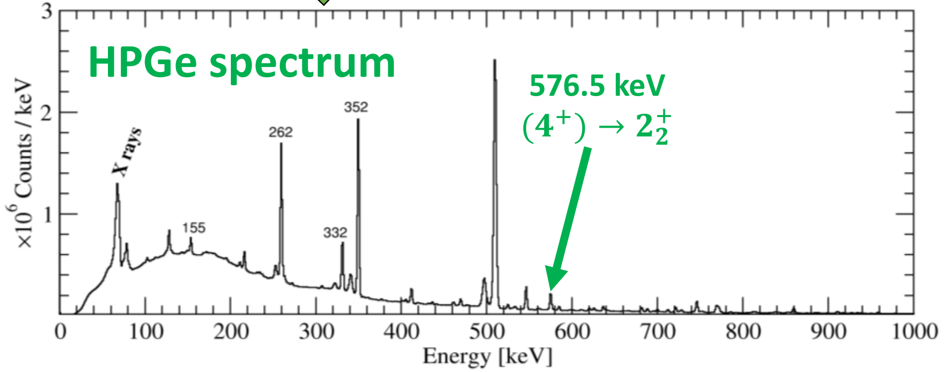
IS641 – Conversion electron spec. of ^{182,184,186}Hg isotopes

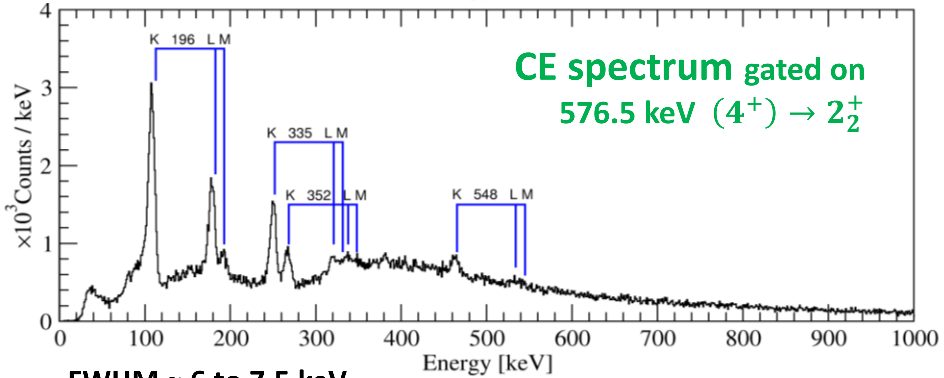
PHYSICAL REVIEW C **102**, 024322 (2020)

Decay studies of the long-lived states in ^{186}Tl

M. Stryjczyk,[1,*] B. Andel,[1,2] A. N. Andreyev,[3,4] J. Cubiss,[5,3] J. Pakarinen,[6,7] K. Rezynkina,[1,8] P. Van Duppen,[1] S. Antalic,[2] T. Berry,[9] M. J. G. Borge,[10,5] C. Clisu,[11] D. M. Cox,[12] H. De Witte,[1] L. M. Fraile,[13] H. O. U. Fynbo,[14] L. P. Gaffney,[5] L. J. Harkness-Brennan,[15] M. Huyse,[1] A. Illana,[16,6,7] D. S. Judson,[15] J. Konki,[5] J. Kurcewicz,[5] I. Lazarus,[17] R. Lica,[11,5] M. Madurga,[5] N. Marginean,[11] R. Marginean,[11] C. Mihai,[11] P. Mosat,[2] E. Nacher,[18] A. Negret,[11] J. Ojala,[6,7] J. D. Ovejas,[10] R. D. Page,[15] P. Papadakis,[15,17] S. Pascu,[11] A. Perea,[10] Zs. Podolyák,[9] V. Pucknell,[17] E. Rapisarda,[5] F. Rotaru,[11] C. Sotty,[11] O. Tengblad,[10] V. Vedia,[13] S. Viñals,[10] R. Wadsworth,[3] N. Warr,[19] and K. Wrzosek-Lipska[20]
(IDS Collaboration)







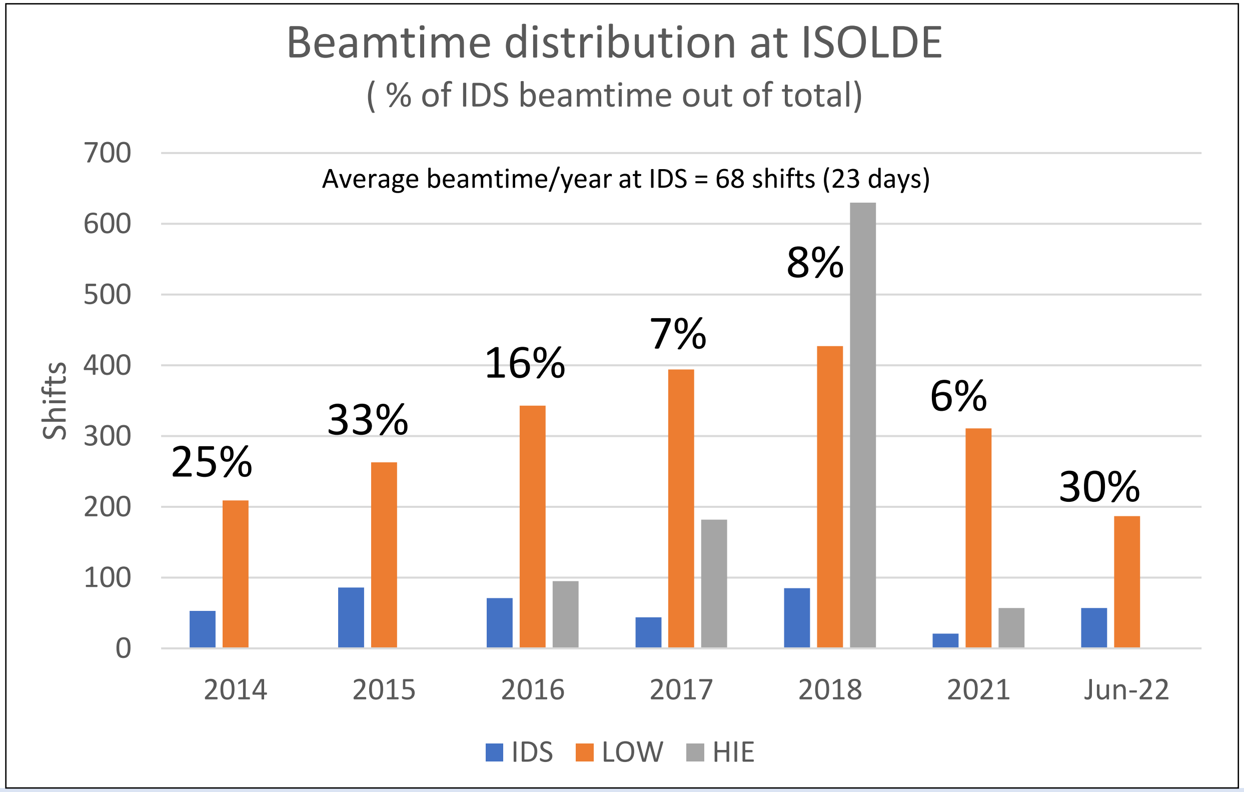
FWHM ≈ 6 to 7.5 keV

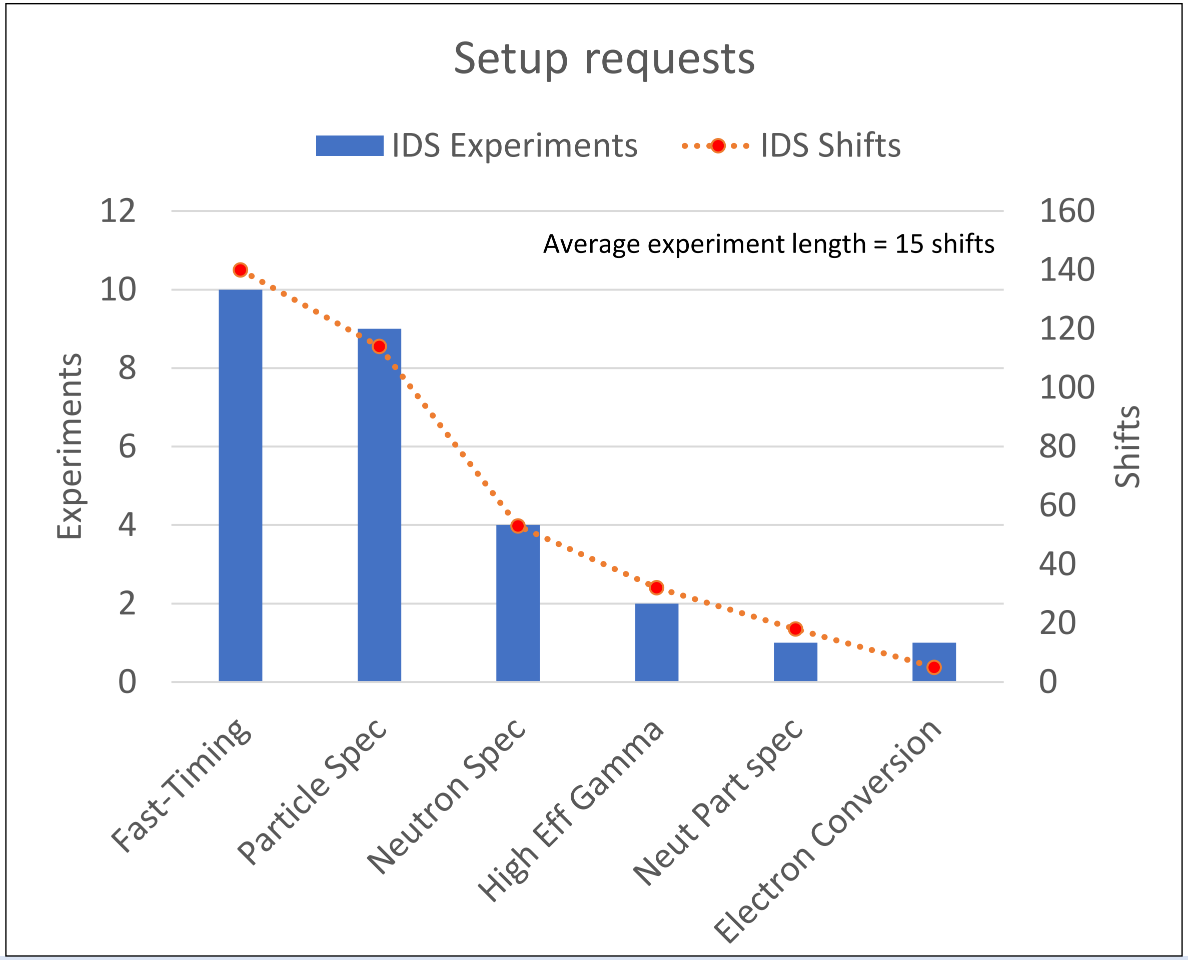
Previous and future experiments at IDS

Statistics from IDS (2014 - 2022)

- Successful experiments: 25 (split in 30 runs)

IS474(b), **IS507**, **IS530(b)**, **IS577**, **IS579(a,b)**, **IS588**, **IS590**, IS599, IS600, **IS605**, IS608(a,b), IS609, **IS610(a,b)**, IS622(a,b), IS632, IS633(a,b), IS641, IS650, IS665, IS685, LOI219, IS659, IS664, LOI216, IS456,

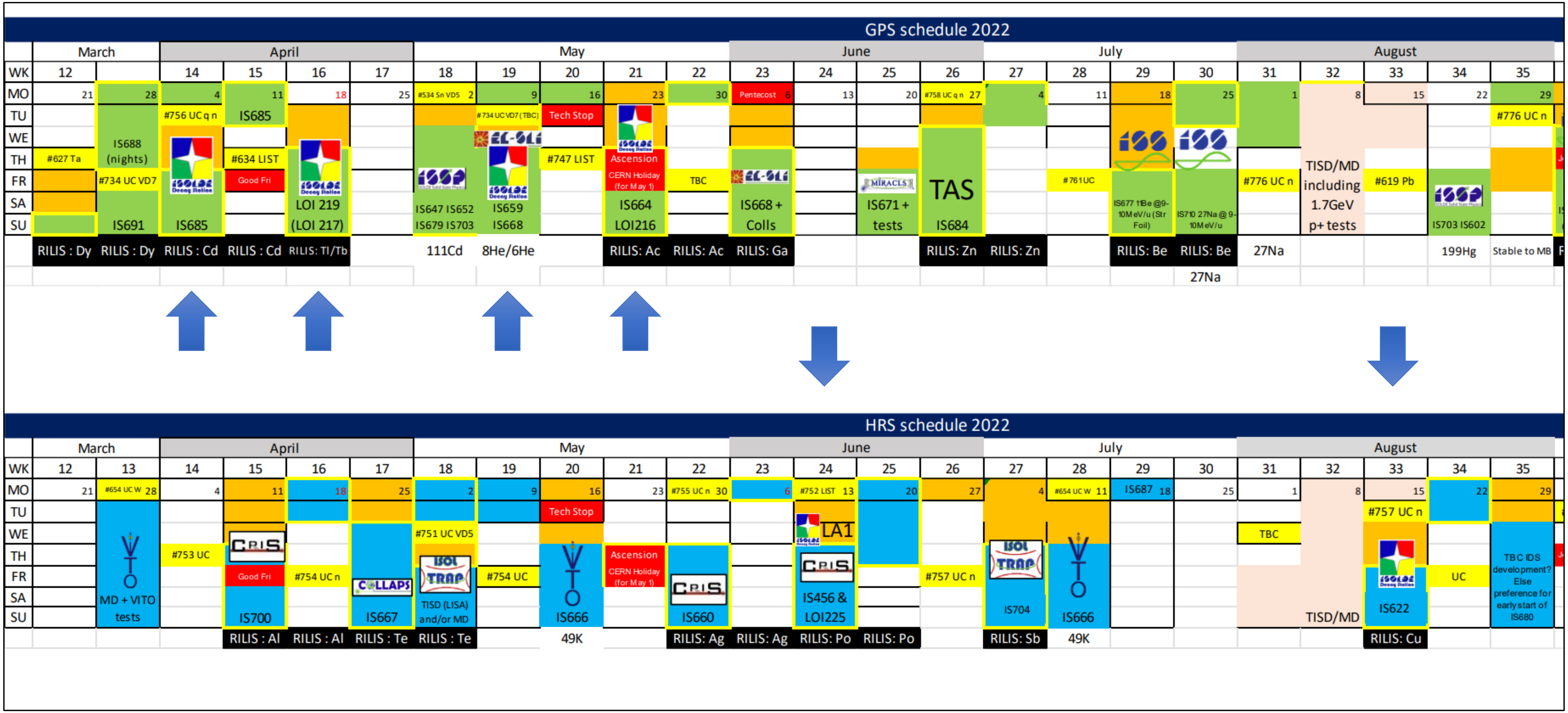




Details about past and future experiments available at: https://isolde-ids.web.cern.ch/#expt

ISOLDE Schedule March – August 2022

(most intensive year for IDS)

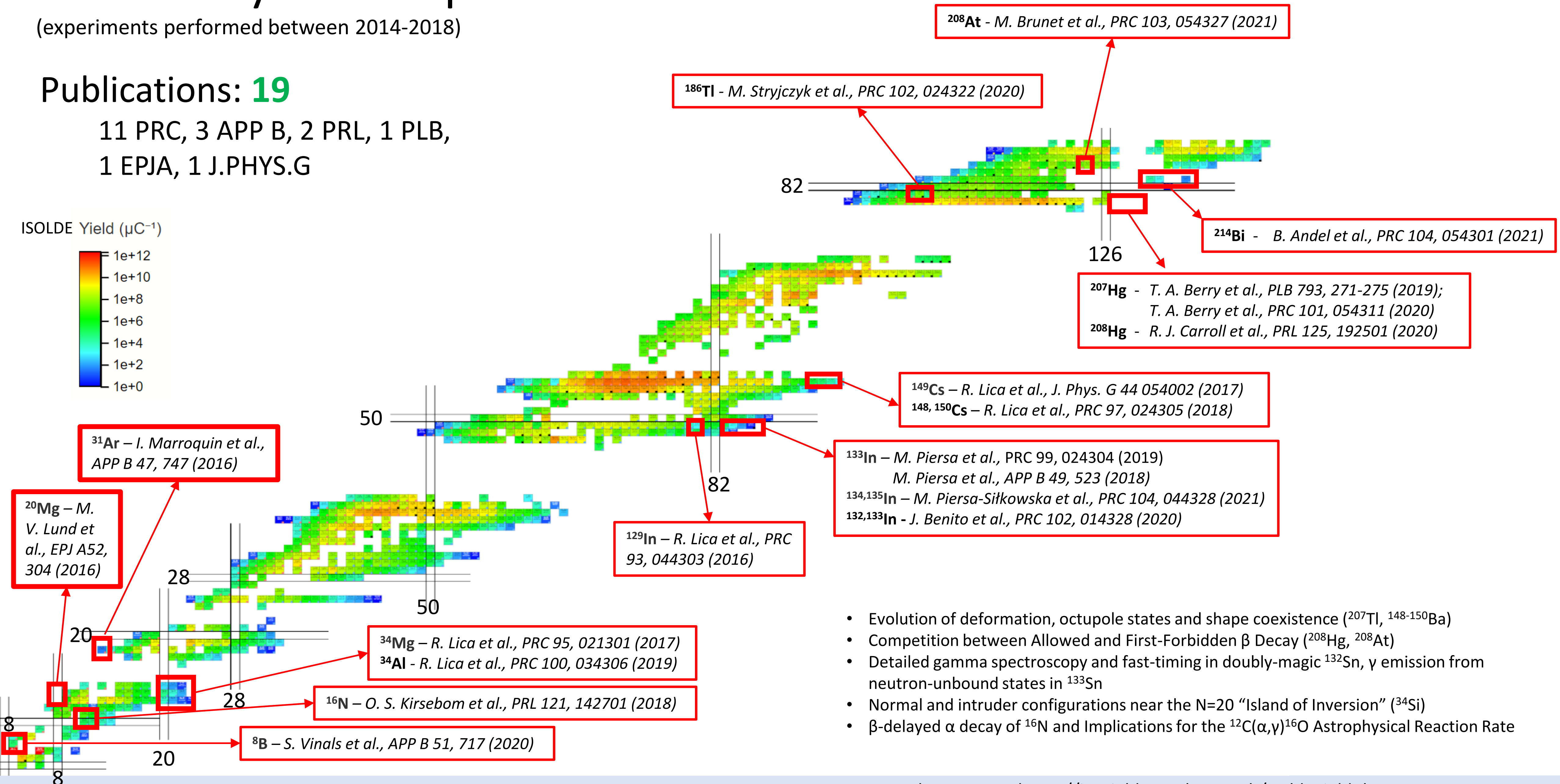


Beta-decay studies published from IDS

(experiments performed between 2014-2018)

Publications: **19**

11 PRC, 3 APP B, 2 PRL, 1 PLB,
1 EPJA, 1 J.PHYS.G

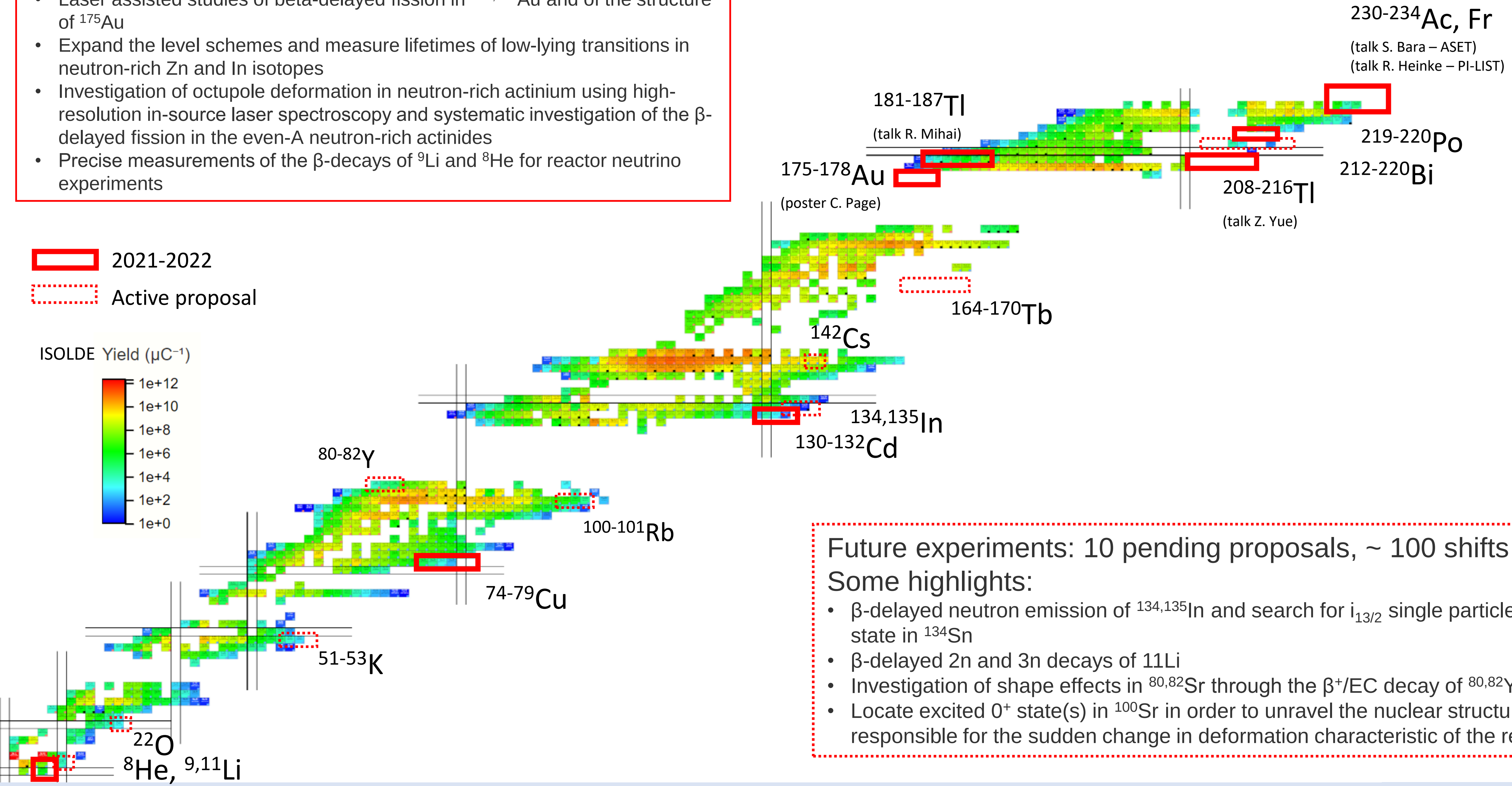


- Evolution of deformation, octupole states and shape coexistence (^{207}Tl, $^{148-150}$Ba)
- Competition between Allowed and First-Forbidden β Decay (^{208}Hg, ^{208}At)
- Detailed gamma spectroscopy and fast-timing in doubly-magic ^{132}Sn, γ emission from neutron-unbound states in ^{133}Sn
- Normal and intruder configurations near the N=20 "Island of Inversion" (^{34}Si)
- β-delayed α decay of ^{16}N and Implications for the ^{12}C(α,γ)^{16}O Astrophysical Reaction Rate

Chart source: https://isoyields2.web.cern.ch/IsoldeYieldChart.aspx

Recent and future experiments at IDS

- Laser assisted studies of beta-delayed fission in ^{178,176}Au and of the structure of ^{175}Au
- Expand the level schemes and measure lifetimes of low-lying transitions in neutron-rich Zn and In isotopes
- Investigation of octupole deformation in neutron-rich actinium using high-resolution in-source laser spectroscopy and systematic investigation of the β-delayed fission in the even-A neutron-rich actinides
- Precise measurements of the β-decays of ^{9}Li and ^{8}He for reactor neutrino experiments



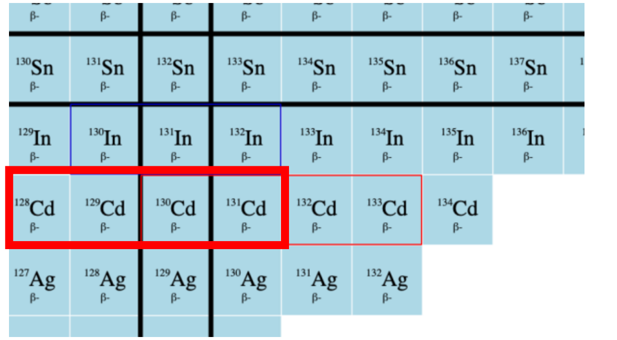
Future experiments: 10 pending proposals, ~ 100 shifts >2023

Some highlights:

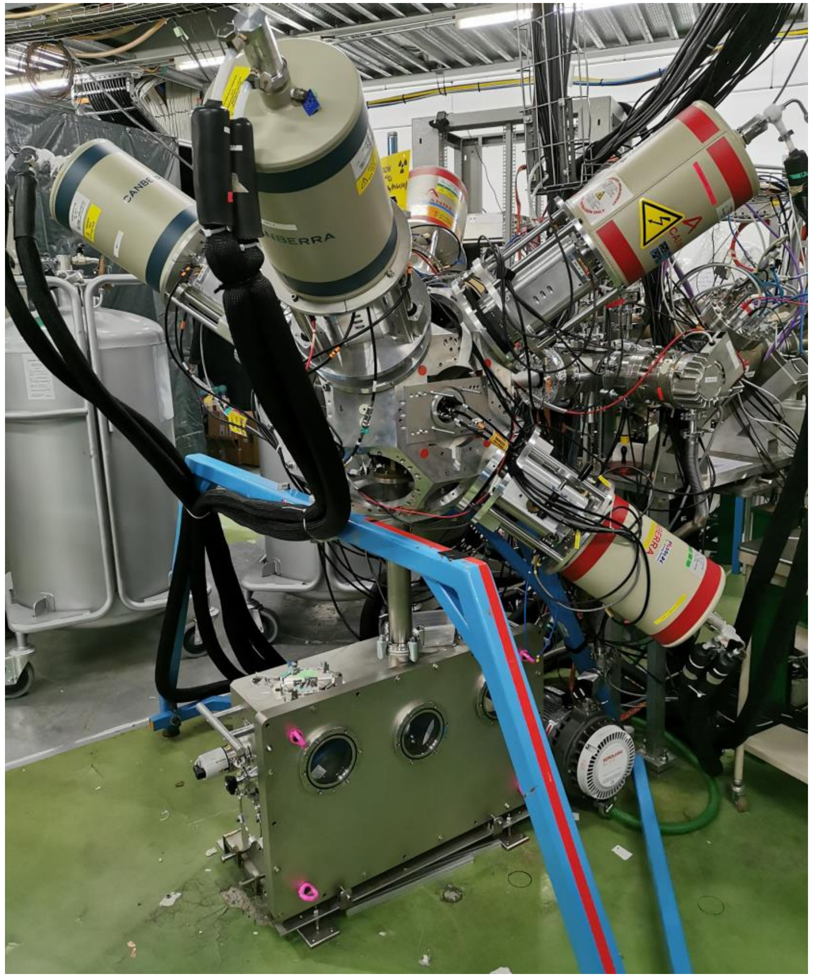
- β-delayed neutron emission of ^{134,135}In and search for $i_{13/2}$ single particle neutron state in ^{134}Sn
- β-delayed 2n and 3n decays of 11Li
- Investigation of shape effects in ^{80,82}Sr through the β⁺/EC decay of ^{80,82}Y
- Locate excited 0⁺ state(s) in ^{100}Sr in order to unravel the nuclear structure responsible for the sudden change in deformation characteristic of the region

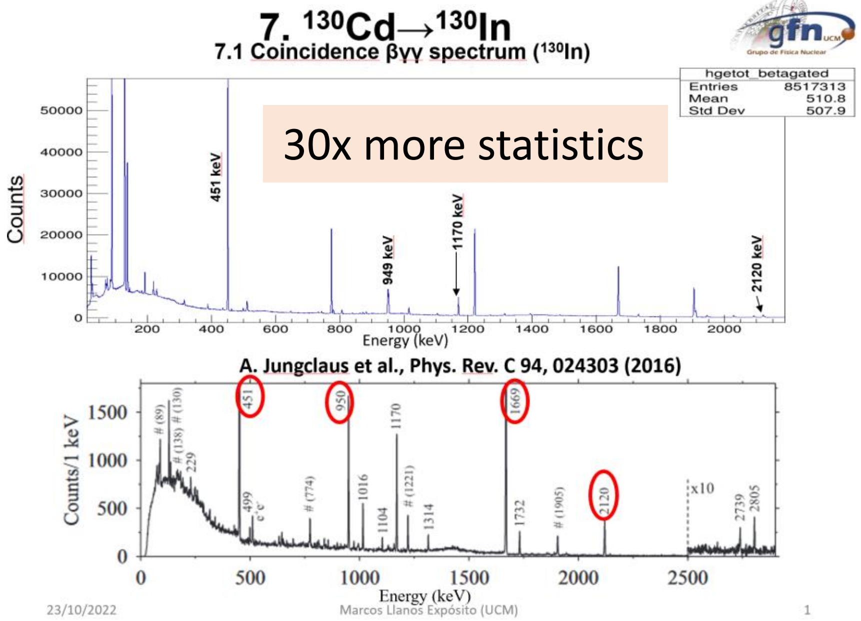
Chart source: https://isoyields2.web.cern.ch/IsoldeYieldChart.aspx

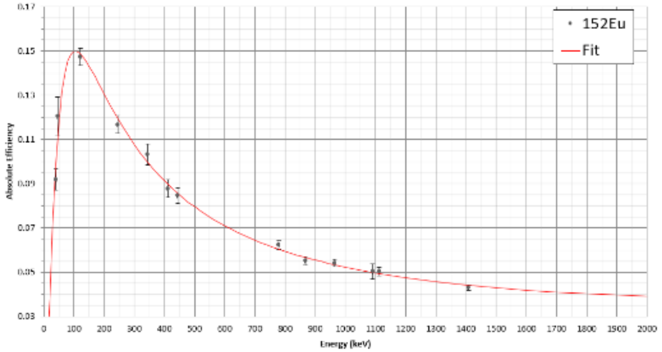
IS685: Beta-decay spectroscopy of neutron-rich Cd isotopes (L.M. Fraile, A. Korgul)



- Investigate the β decay of $^{130-133}$Cd at ISOLDE using high-resolution gamma spectroscopy and fast timing.
- Evolution of shell structure in the vicinity of ^{132}Sn: Single particle states, Core excited configurations, proton-neutron couplings, Electromagnetic transition probabilities
- Yields below expectation: ^{130}Cd: ~260 ions/uC ; ^{131}Cd: ~7 ions/uC
  (UCx Target + Quartz line + Neutron Converter + RILIS)



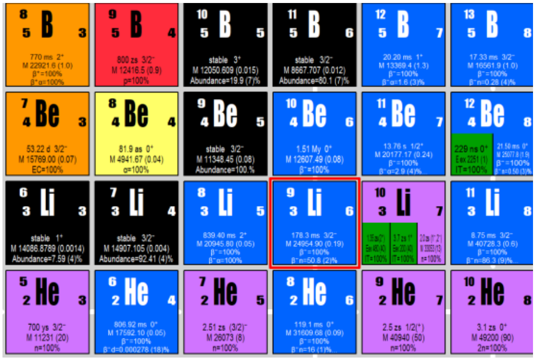




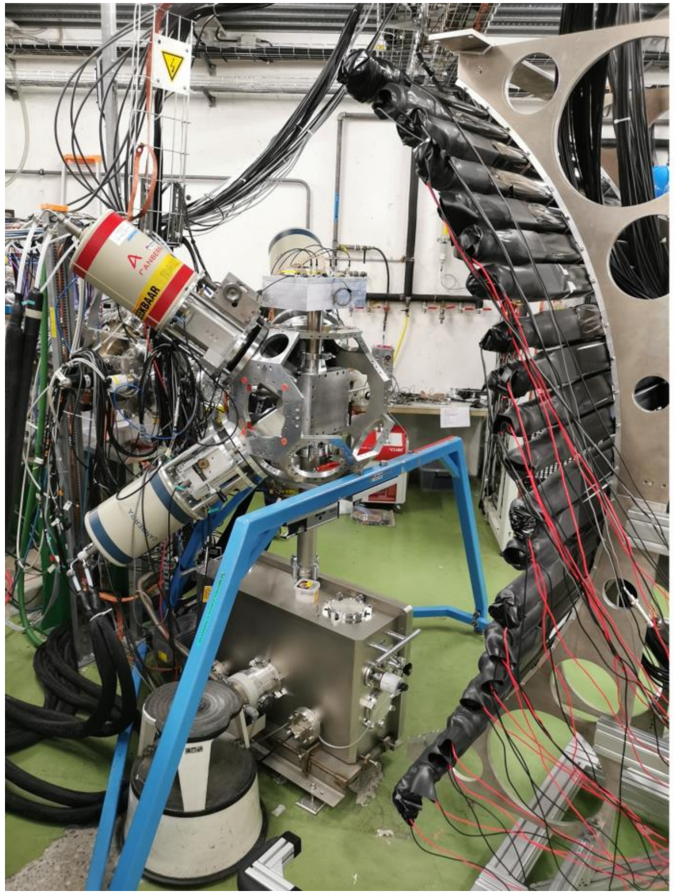
Courtesy of Luis Fraile, Marcos Llanos Exposito (Uni. Complutense Madrid)

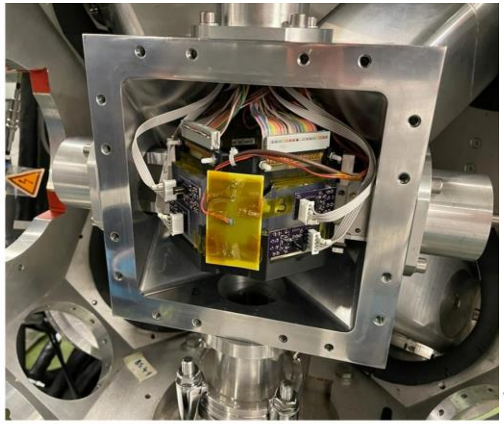
IS659: Precise measurements of the β-decays of ^{9}Li and ^{8}He for reactor neutrino experiments (H.O.U. Fynbo)

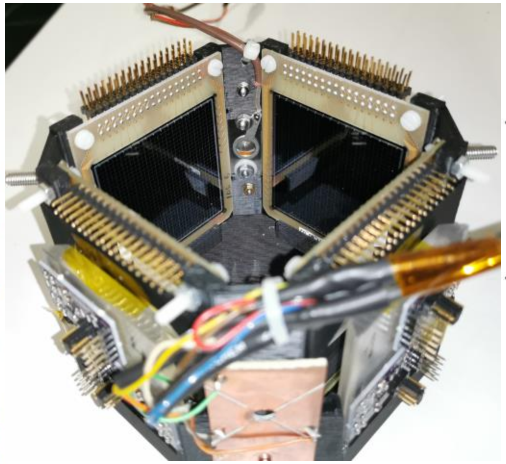
- ^{9}Li and ^{8}He -> some of largest cosmogenic background sources for reactor neutrino experiments
- Need to extract more precise energy levels and branching ratios for ^{9}Li and ^{8}He and decay products.
- 2022: intense production of ^{8}He (UC target)



New IDS configuration: Neutron+Particle spectroscopy

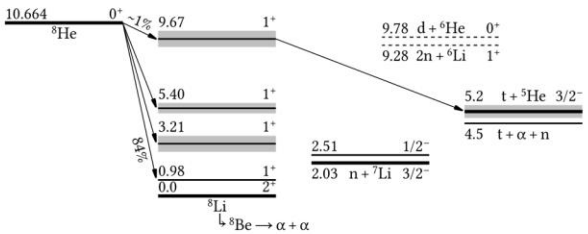


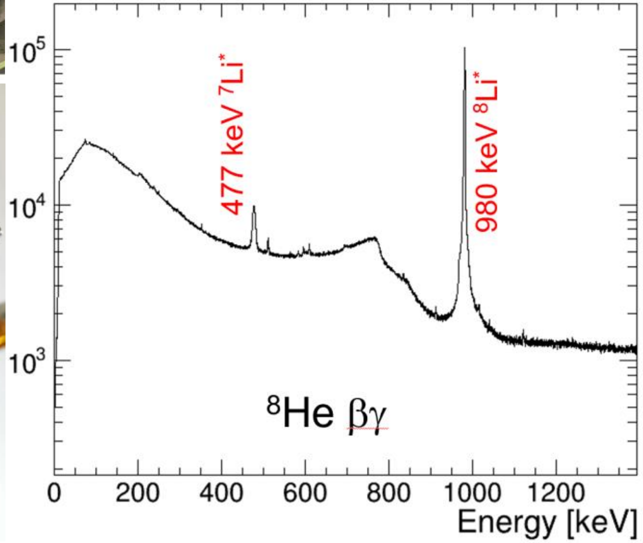


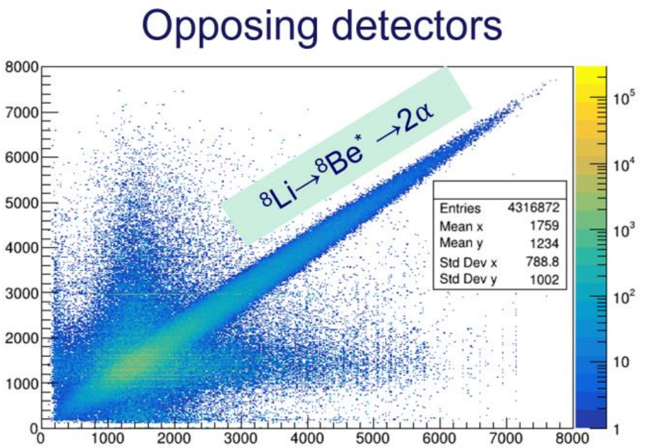


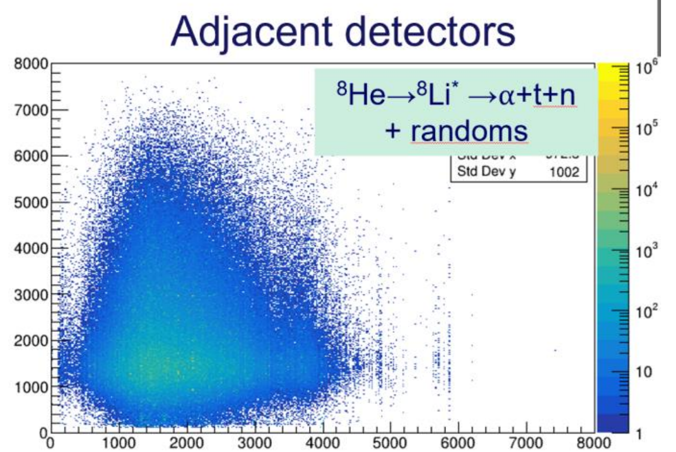
Measured spectra

Preliminary data analysis









Courtesy of Erik Jensen, Hans Fynbo (Uni. Aarhus)

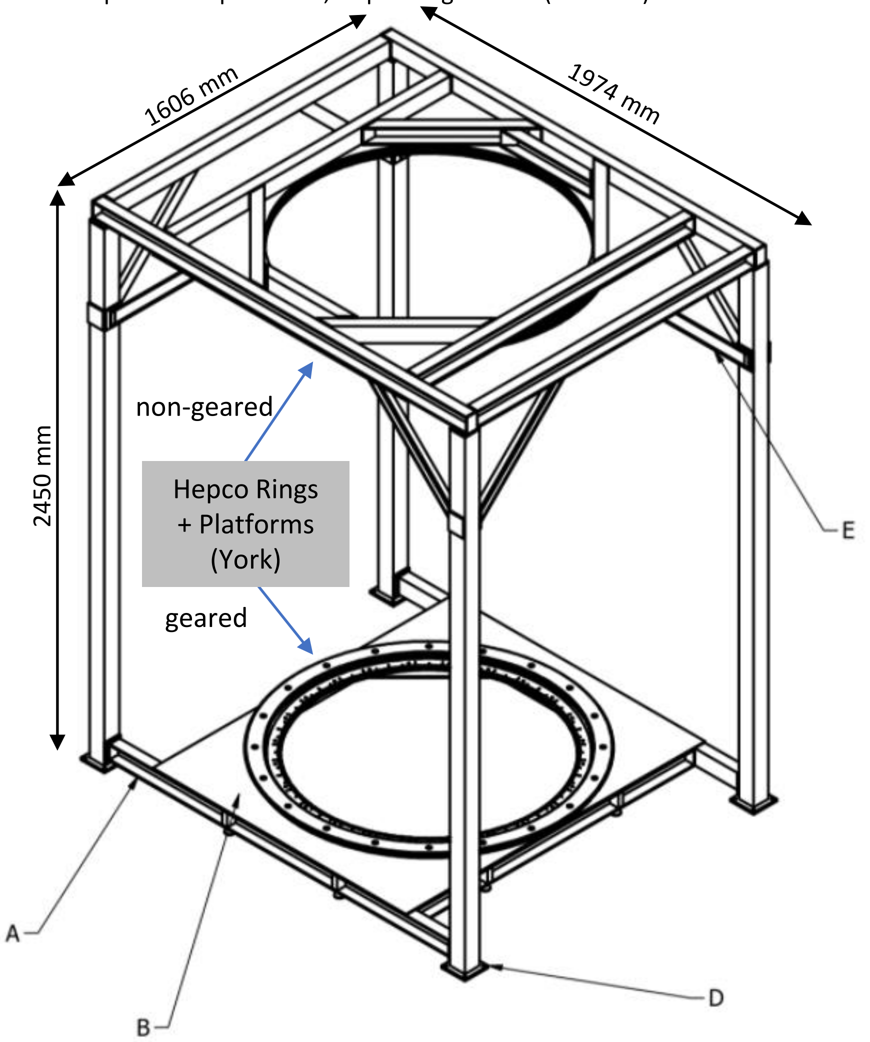
Future developments at IDS

New IDS Structure

- Design finalized (Uni. of Liverpool, D. Seddon, 05.03.2021)

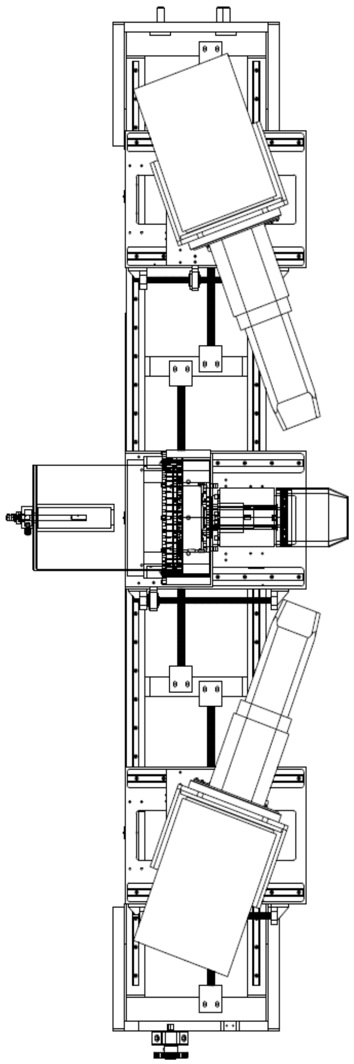
Outer Frame

Pillars - UTK (R. Grzywacz, M. Madurga)
Top+Bottom platforms, Hepco rings – York (J. Cubiss) + IDS funds

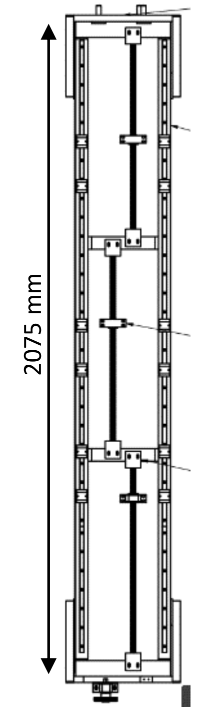


Bracket

University of York (J. Cubiss) + IFIC + UCM + FUW + IFIN – 2 full brackets, 3 more after validation

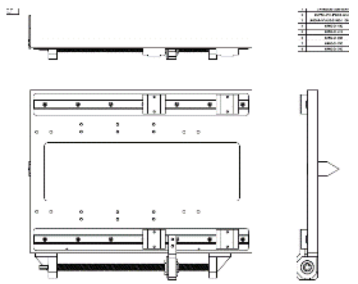


Vertical gantry support

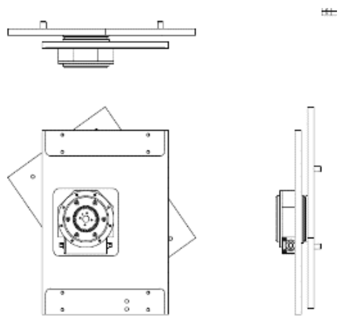


Ge Detector Track

Carriage plate

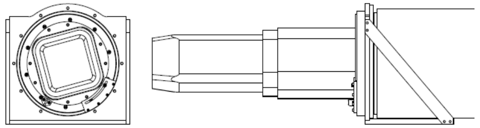


Rotating plate



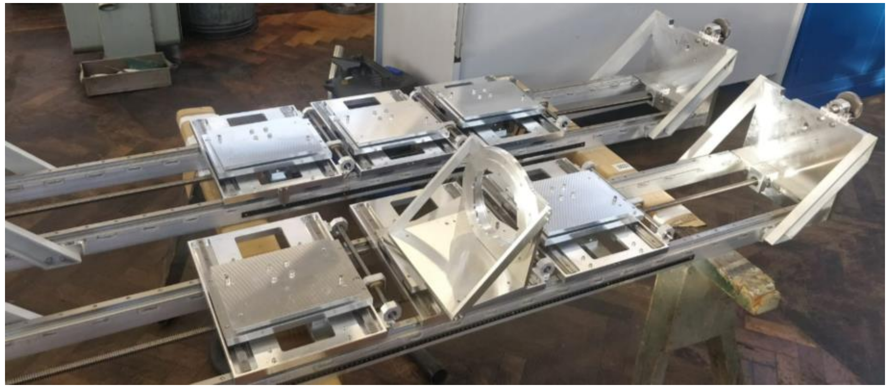
Detector plate

University of Western Cape (N. Orce) – new design for other detector types



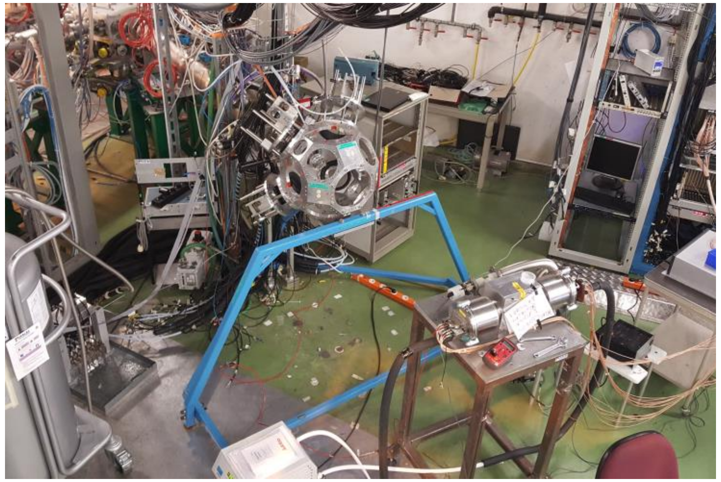
New IDS Structure

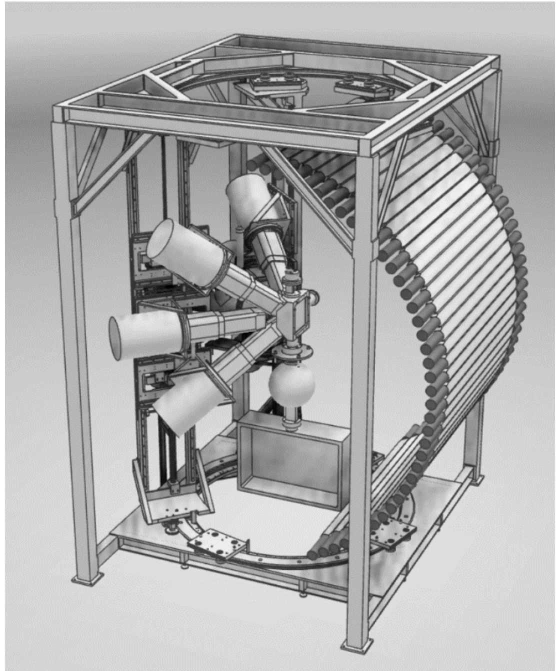
- Oct 2022: All parts arrived at York



- Nov 2022: assembled at York

- Dec 2022 – Mar 2023: removal of old structure from IDS, floor repair, installation of new structure

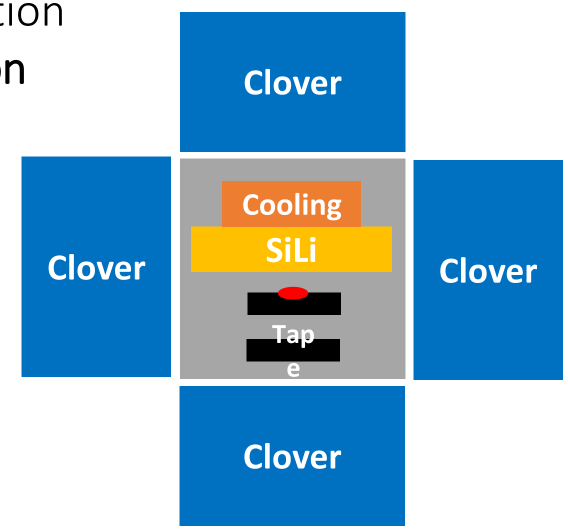




Decay Station 2 @ IDS

Secondary detection setup away from implantation point to:

1. Measure decays of long-lived nuclei/decay products
2. Provide
   (a) **High-resolution CE detectors** ≈3 keV resolution
   (b) **High-efficiency low-energy gamma detection**
   (c) **High-efficiency silicon setup** (close geom)



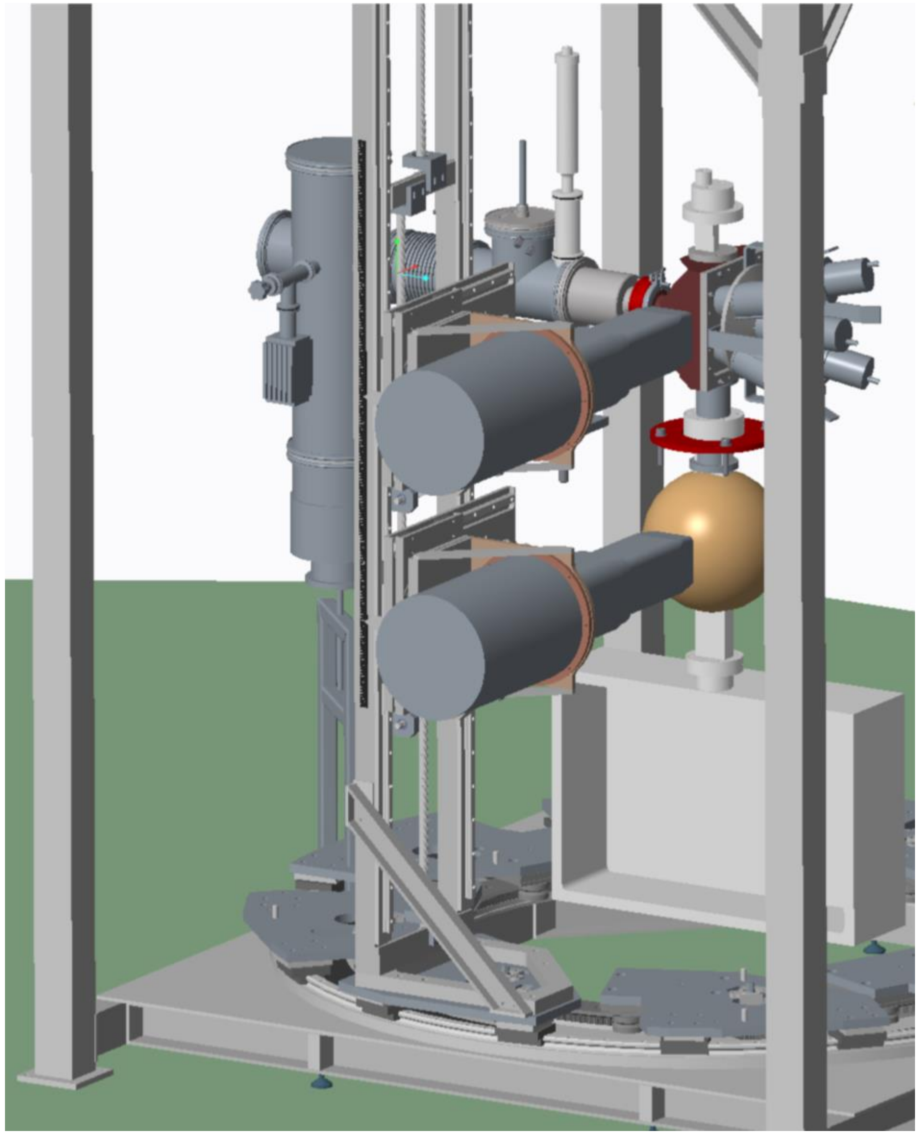
Physics cases:

- **Limits of n-rich nuclei @ ISOLDE**
long-lived enough $T_{1/2}(^{232}Fr)$≈5 s, $T_{1/2}(^{232}Ra)$≈30 s

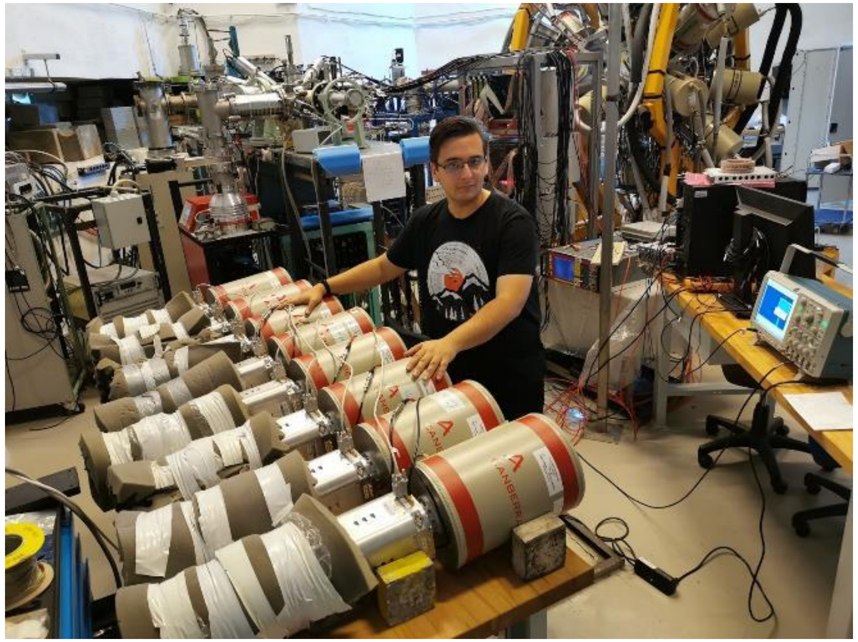
- **β-delayed fission in neutron rich Fr and Ac,**
$T_{1/2}$ of minutes. DS2 large-area Si placed in close geometry would give factor of ≈3 in solid angle compared to WM, beta-fission coincidences.

- **β-decay study of n-rich isotopes in N>126, Z<82**, investigate single-particle states in $^{210-215}$Tl,Pb, which have $T_{1/2}$>30 s

2 chambers: implantation and decay

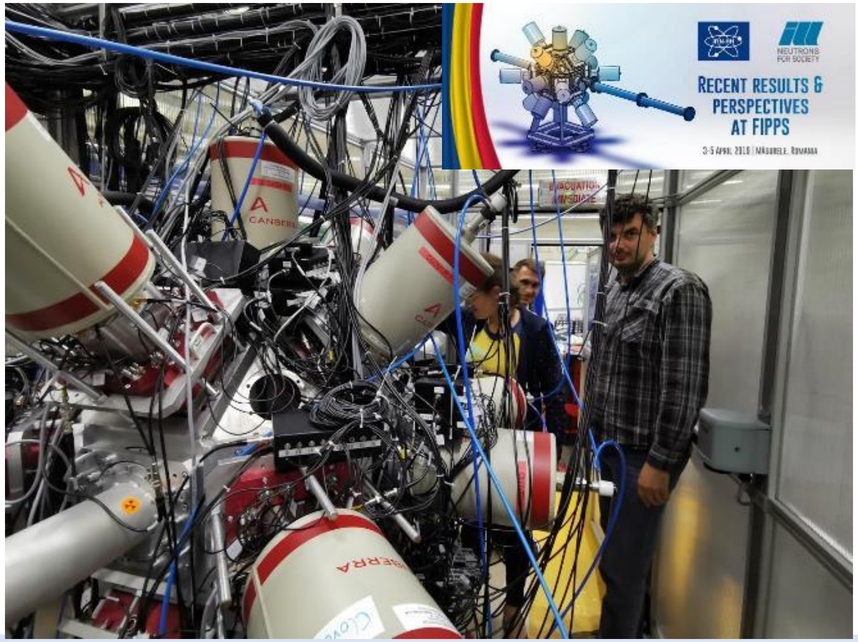


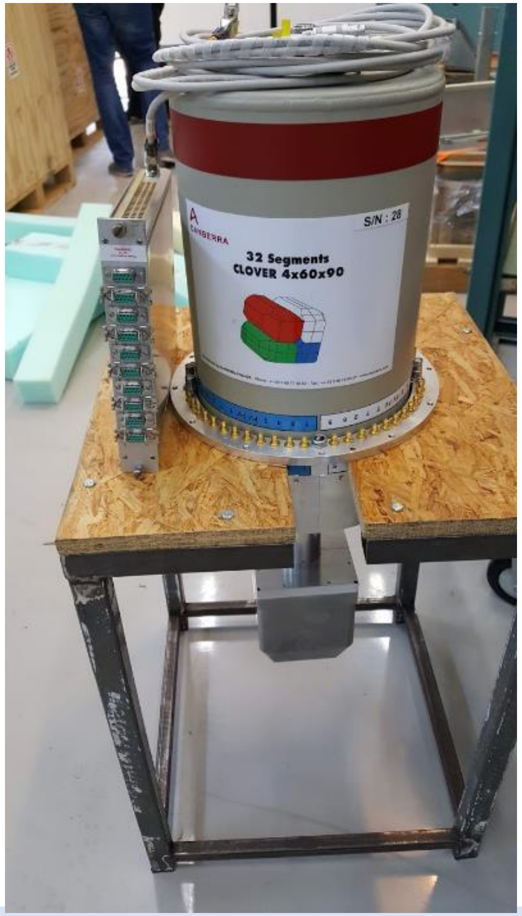
>15 Available HPGE detectors

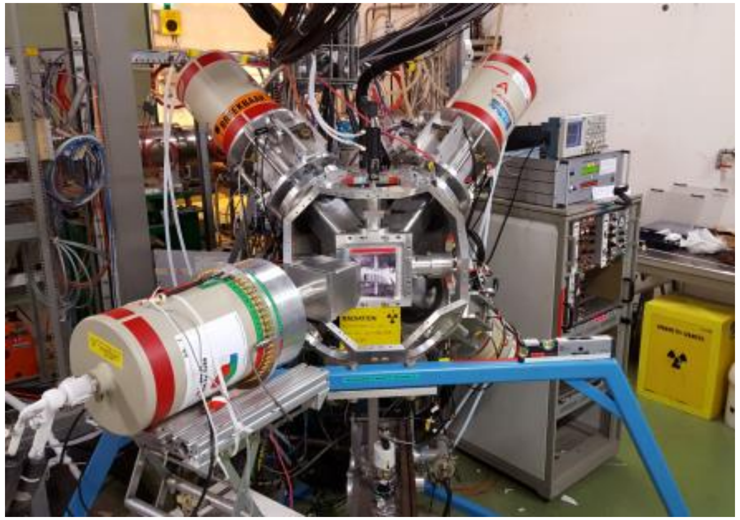


Permanent at IDS: 6 HPGe Clover detectors
2 standard window (IFIN-HH), 4 thin window (KUL)

+ 8 HPGe Clover detectors (IFIN-HH)
(to be shared with the FIPPS setup - ILL, Grenoble)







+ 1 Tigress type HPGe Clover
(already used at IDS)

+ Others (coaxial, x-ray, etc.)

XIA Pixie-16 500MHz digital fast-timing tests at IDS

(expand the current analog fast-timing system to accommodate more detectors)

- Current limit of an **analog** system for 1.5” $LaBr_3$(Ce) detectors: FWHM = 155 ps
- Best result achieved offline by a **digital** system (2 GHz): FWHM = 140 ps

  V. Sanchez-Tembleque, V. Vedia, L.M. Fraile, S. Ritt, J.M. Udias, NIM A 927 54-62 (2019)

- Online digital fast-timing for 2” $LaBr_3$(Ce) with a 500MHz module: FWHM = 320 - 409 MHz

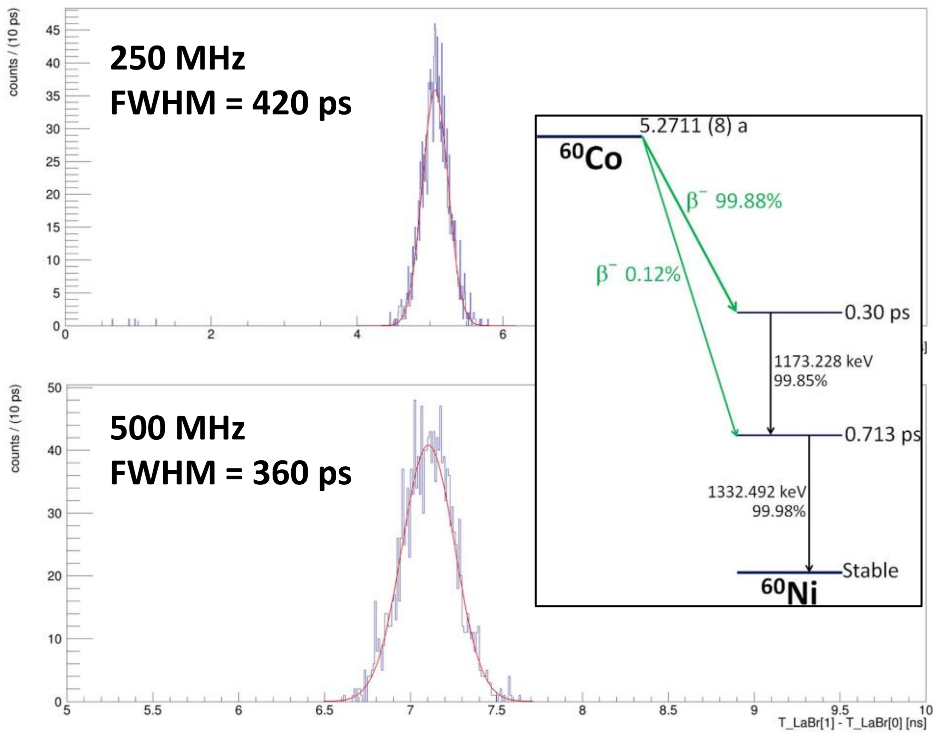
  L. Msebi, V.W. Ingeberg, P. Jones et al., NIM A 1026 166195 (2022)


Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 1026, 1 March 2022, 166195

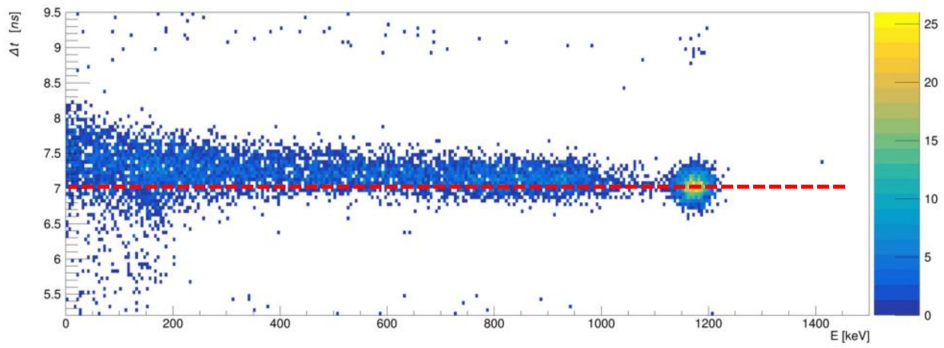
A fast-timing array of 2” x 2” $LaBr_3$:Ce detectors for lifetime measurements of excited nuclear states

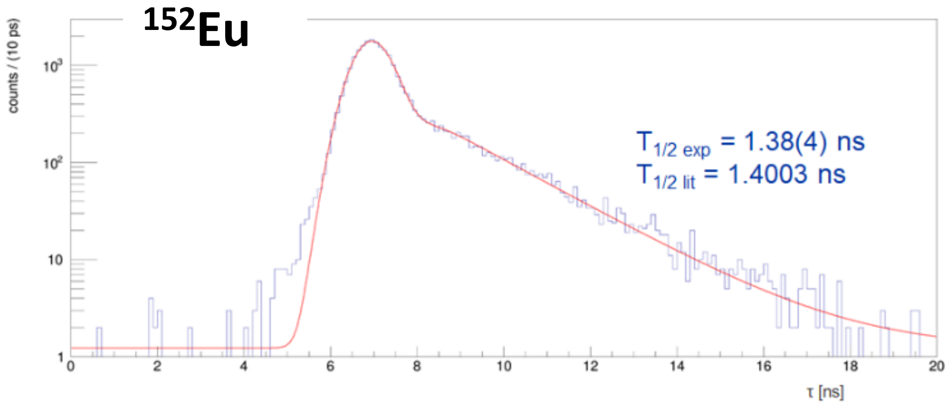
L. Msebi [a, b], V.W. Ingeberg [c], P. Jones [b], J.F. Sharpey-Schafer [f], A.A. Avaa [b, e], T.D. Bucher [a], C.P. Brits [b, d], M.V. Chisapi [b, d], D.J.C. Kenfack [b, d], E.A. Lawrie [b], K.L. Malatji [b, d], B. Maqabuka [a, b], L. Makhathini [b], S.P. Noncolela [a, b], J. Ndayishimye [b], A. Netshiya [b], O. Shrinda [g], M. Wiedeking [b, e], B.R. Zikhali [a, b]

Confirmed at IDS (Nov 2022)



Tests conducted at IDS by Chris Page, Zixuan Yue (PhD Students, Uni. York)





On-line TDPAC @ IDS

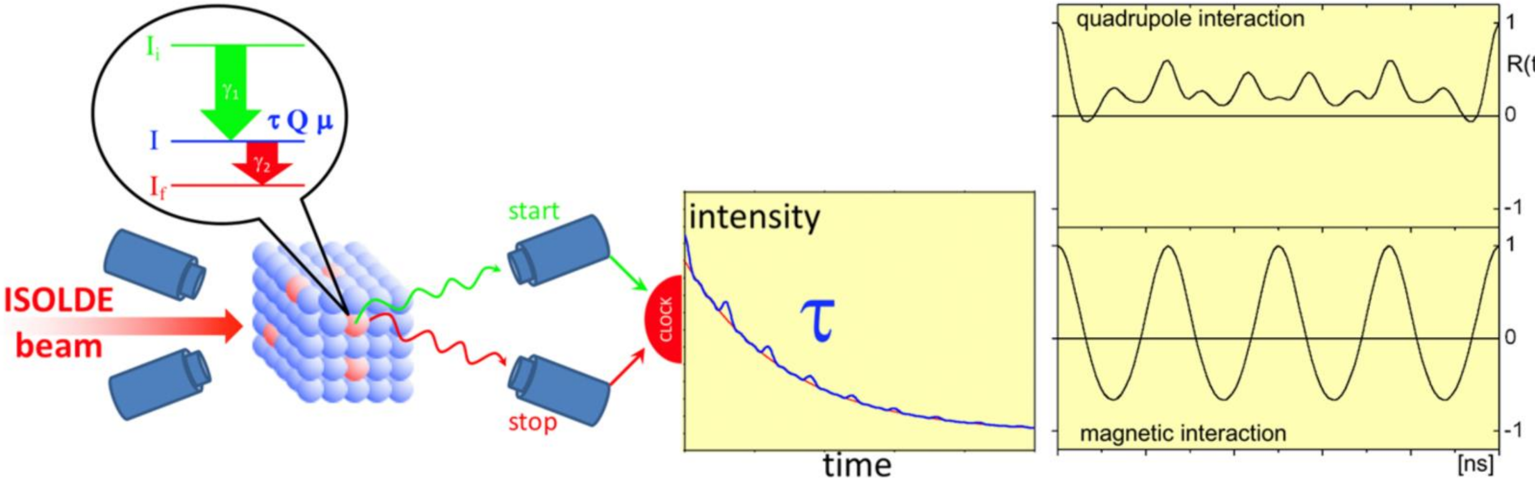
Nuclear moment studies of short-lived isomers (~ 1 ns – 1 μs) using

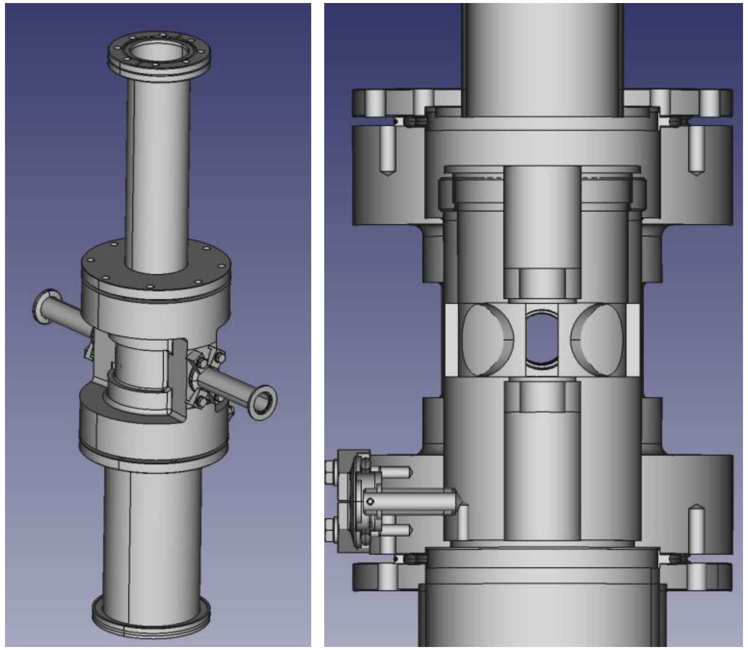
<u>T</u>ime <u>D</u>ependent <u>P</u>erturbed <u>A</u>ngular <u>C</u>orrelations

- moment studies on neutron-rich isomeric states non accessible by any other means;
- population after β-decay ($\beta - \gamma - \gamma$), the spin orientation provided through the angular correlations
- TDPAC – standardly used in solid-state physics (long-lived isotopes). ***With IDS one can go <u>on-line</u>.***

Design and manufacturing currently on-going for the IDS TDPAC chamber (IFIN-HH, IJCLAB)

-> to be completed mid 2023



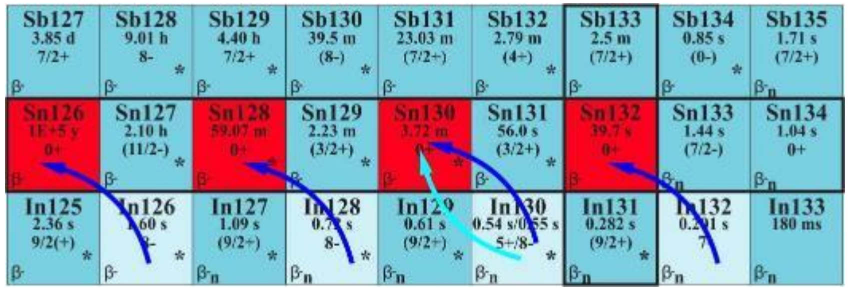


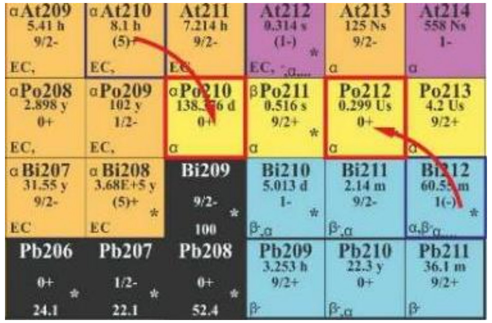
First physics cases considered:

- magnetic and quadrupole moments in the ***neutron-rich Sn isotopes towards N=82*** (**<u>IS673</u>**)

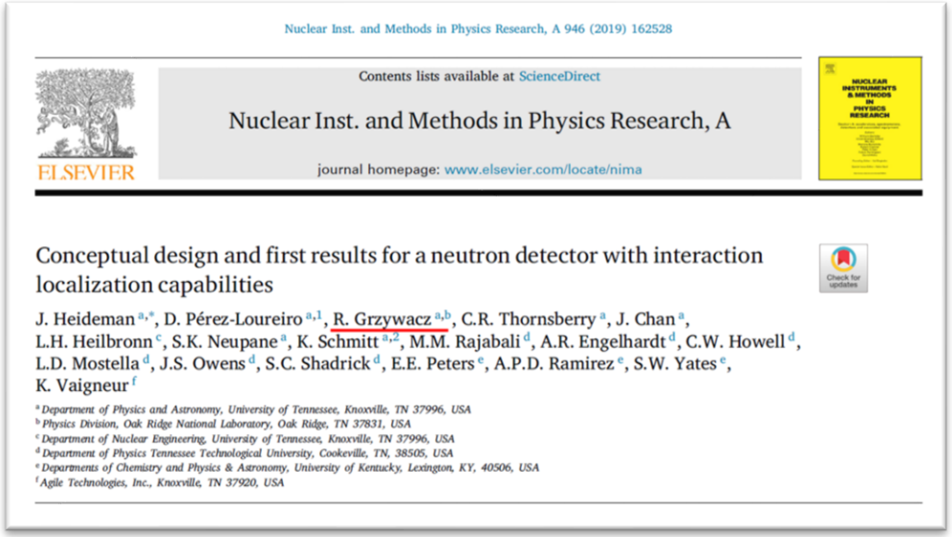
5^- ($h_{11/2}\otimes s_{1/2}$), 7^- ($h_{11/2}\otimes d_{3/2}$), 10^+ ($h_{11/2}^2$) isomers

- ***seniority vs. cluster structure*** round ^{208}Pb (**<u>LOI239</u>**) starting with ^{212}Po





Future neutron spectroscopy at IDS


Nuclear Inst. and Methods in Physics Research, A 946 (2019) 162528

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

ELSEVIER

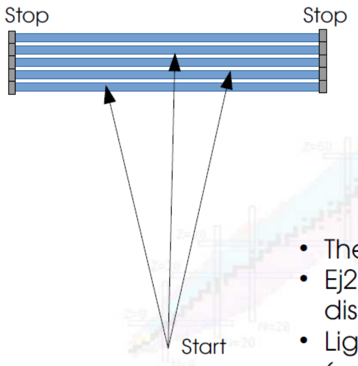
Conceptual design and first results for a neutron detector with interaction localization capabilities

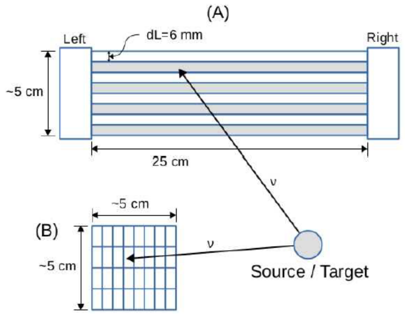
J. Heideman[a,*], D. Pérez-Loureiro[a,1], R. Grzywacz[a,b], C.R. Thornsberry[a], J. Chan[a], L.H. Heilbronn[c], S.K. Neupane[a], K. Schmitt[a,2], M.M. Rajabali[d], A.R. Engelhardt[d], C.W. Howell[d], L.D. Mostella[d], J.S. Owens[d], S.C. Shadrick[d], E.E. Peters[e], A.P.D. Ramirez[e], S.W. Yates[e], K. Vaigneur[f]

[a] Department of Physics and Astronomy, University of Tennessee, Knoxville, TN 37996, USA
[b] Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
[c] Department of Nuclear Engineering, University of Tennessee, Knoxville, TN 37996, USA
[d] Department of Physics Tennessee Technological University, Cookeville, TN, 38505, USA
[e] Departments of Chemistry and Physics & Astronomy, University of Kentucky, Lexington, KY, 40506, USA
[f] Agile Technologies, Inc., Knoxville, TN 37920, USA

NEXT concept: tiled thin scintillator with the side light readout.

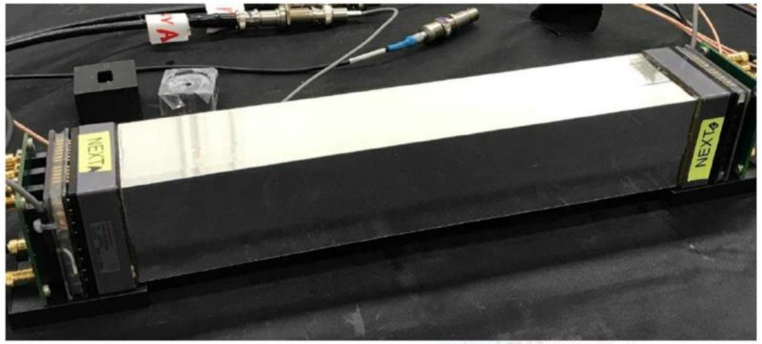
Neutron time-of-flight detector with good timing (~0.5 ns) and neutron/gamma discrimination capabilities for decay and reactions studies. should measure 100 keV to 10 MeV neutrons

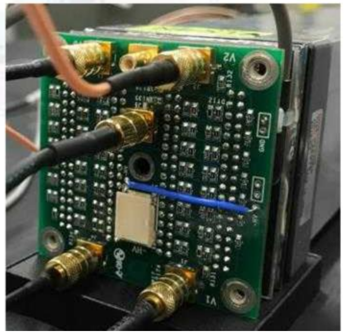




- The interaction localization improves energy resolution
- Ej276 plastic scintillator allows for neutron-gamma discrimination.
- Light readout with segmented photomultipliers (or silicon photomultipliers)

Segmented scintillator with multianode PMT position sensitive light readout.





J. Heideman, D. Pérez-Loureiro, R. Grzywacz et al.

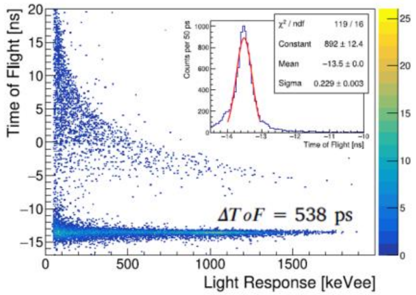
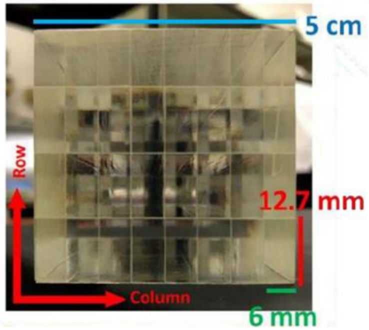
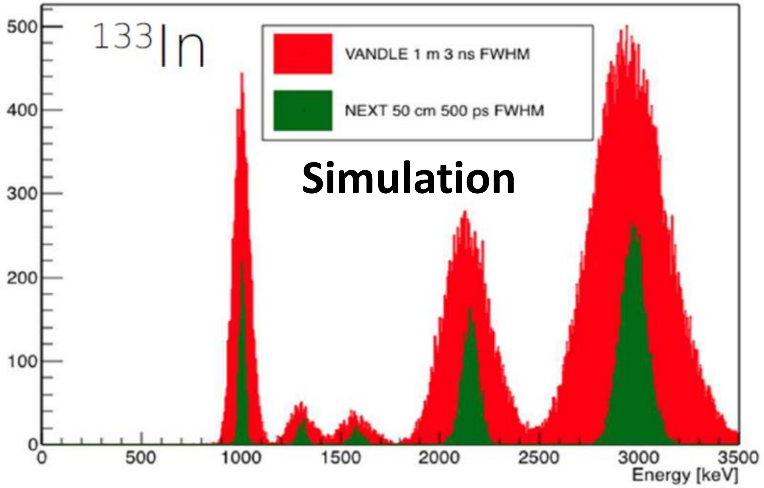


Fig. 14. Two-dimensional histogram of ^{252}Cf neutron ToF versus light response in the ESR-covered EJ-276 stop detector. The inset is a projection of the gamma-ray peak in the ToF spectrum and has ΔToF=538 ps (50 keVee threshold). The ToF data are shown here with no offset to account for inherent timestamp differences between START and STOP acquisition channels.





$$\left(\frac{\Delta T}{T}\right) \sim \left(\frac{2\Delta L}{L}\right)$$

Design parameters (cost and technical feasibility)
- reduce TOF length (L)
- optimal segmentation
- best timing resolution
- electronic readout

Conclusions

- High demand for decay spectroscopy studies at ISOLDE-CERN
- IDS is continuously growing and developing a high variety of techniques applicable in nuclear spectroscopy
- Strong support from the IDS Collaboration – new contributing members are welcome to join
- IDS Collaboration meeting on **2 December 2022**

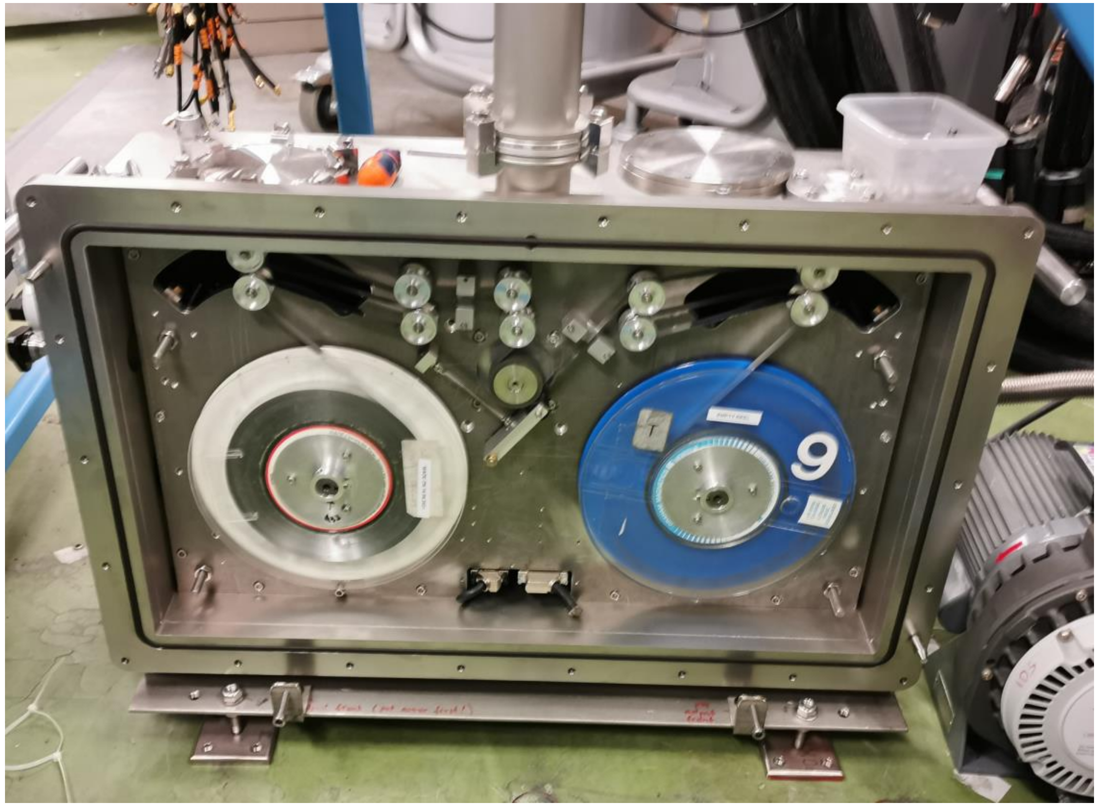
(CERN Council Chamber, 16:00-18:30)

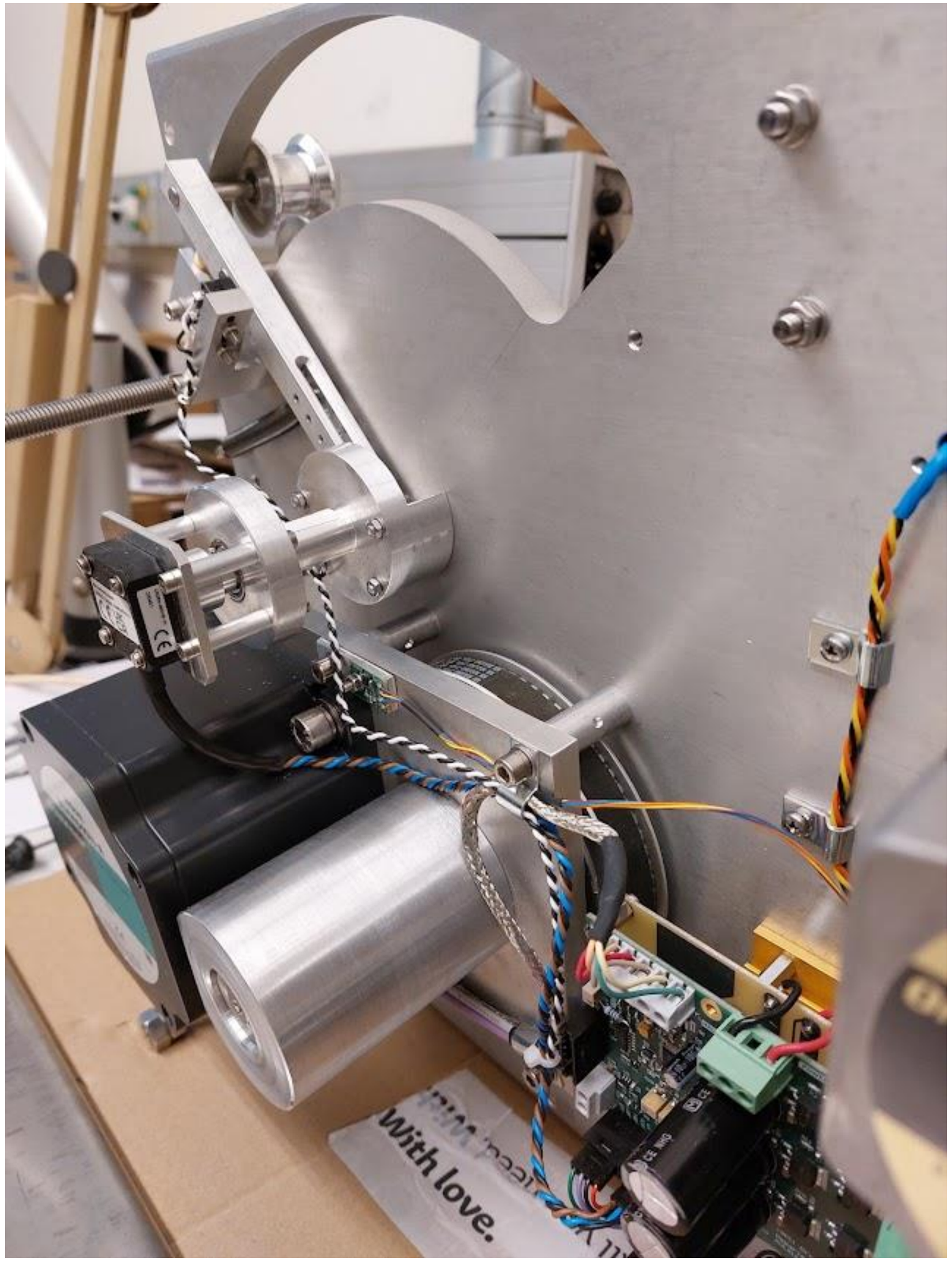
Thank you for your attention!

Extra slides

IDS Tapestation upgrades

- a copy was made at KUL and the motor with integrated gearhead was replaced. It works now with a belt, like in the old tape station. The reason is that we suppose it will work better/longer in vacuum.
- a testing bench was build at KUL to move the tape to beamline height for testing with different speeds and settings to have the tape as fast, and in the same time, as stable as possible. This will fix the current tape 'flutter' problem which limits the maximum speed to half of what should be possible



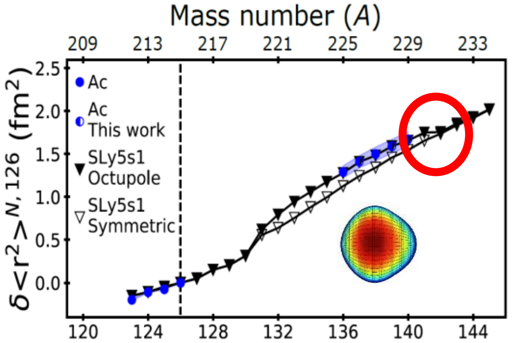


Courtesy of H. De Witte, KUL

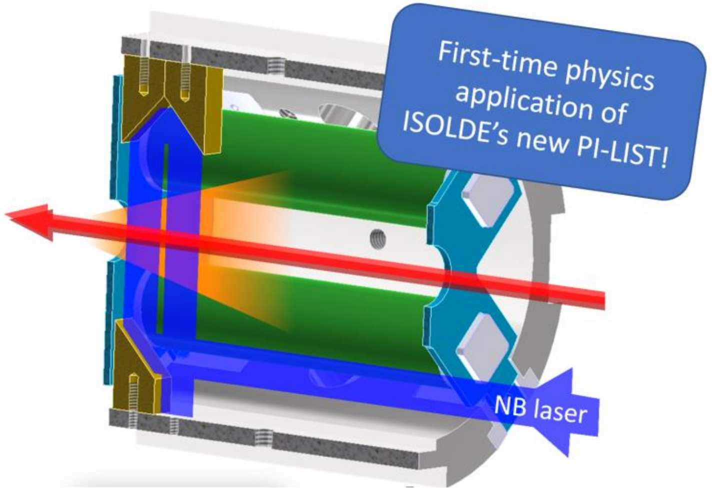
IS664: Investigation of octupole deformation in neutron-rich actinium using high-resolution in-source laser spectroscopy (R. Heinke et al.)
LOI216: β-delayed fission of neutron-rich actinides (A. N. Andreyev et al.)

- $^{224\text{-}231}$Ac: Abrupt change in mean square charge radii confirmed
- ^{230}Ac: upper limit for the βDF probability of ~10^{-10}

  (previous literature value of ~10^{-8})

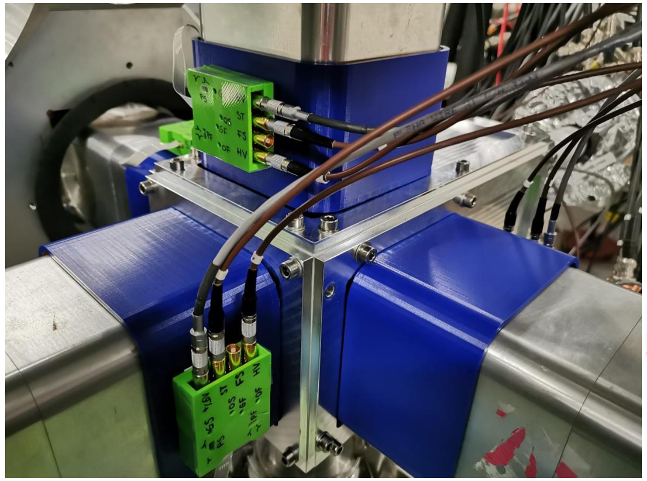


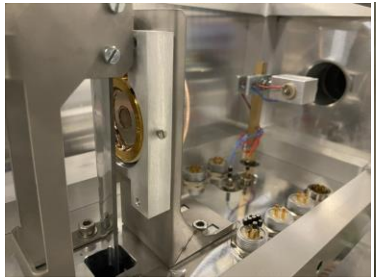
IDS + ASET (LA1) + Ion Counter

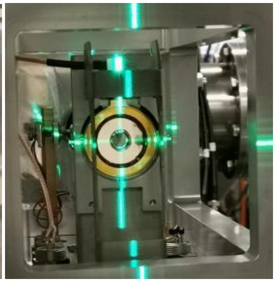


PI-LIST = Perpendicularly Illuminated Laser Ion Source and Trap

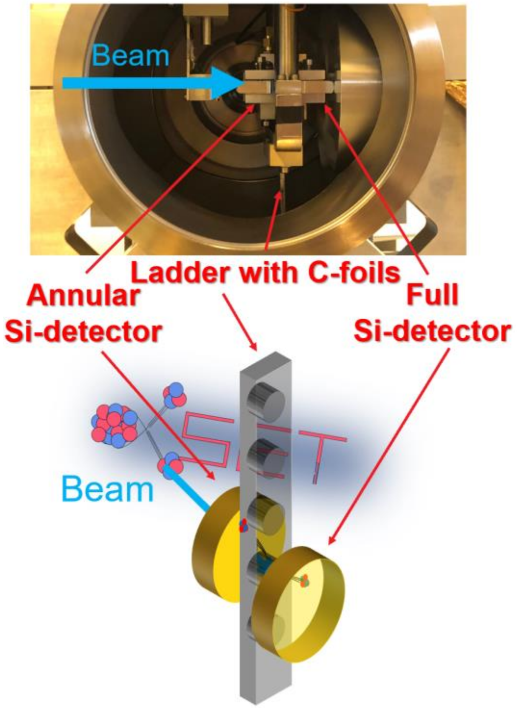
IDS Cubic Chamber + Annular Si



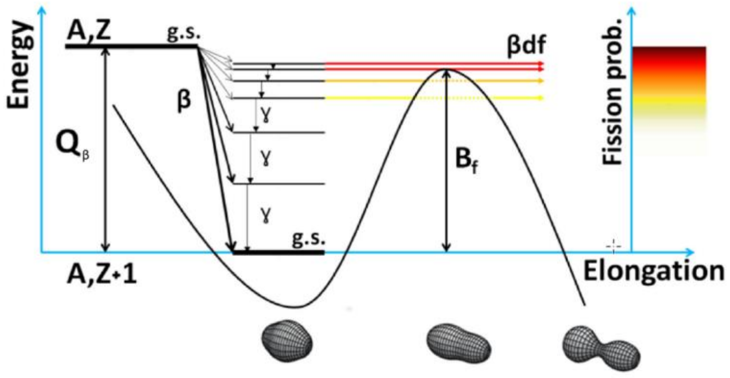




ASET @ LA1

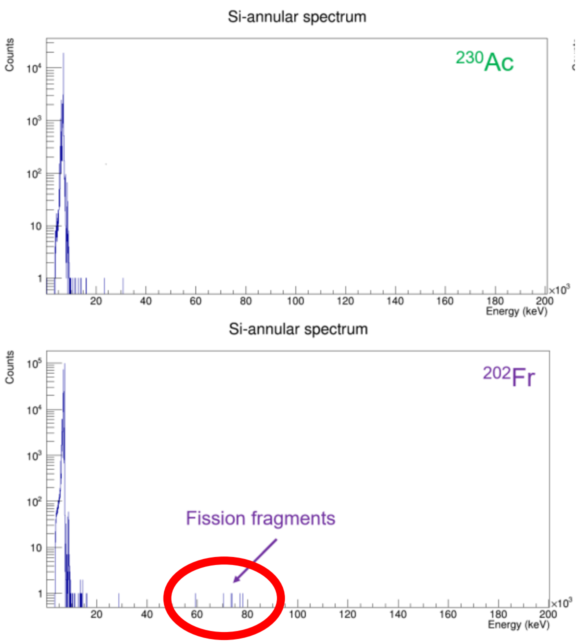


β-delayed fission (βDF) is a two-step process, where the β-decay of a nucleus is followed by the fission of the daughter



The best condition for it to happen is when

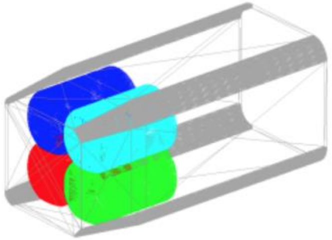
$$Q_\beta - B_f \gtrsim -3\ \text{MeV}$$

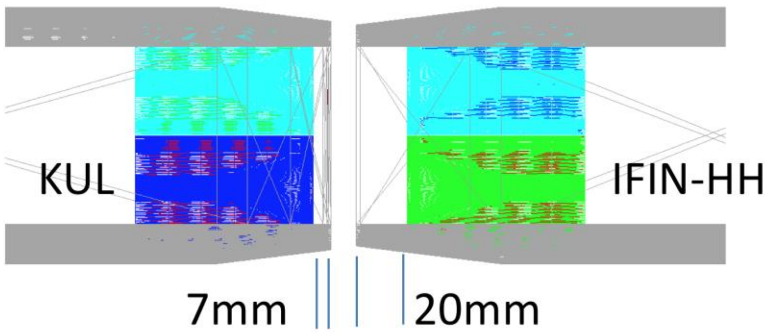


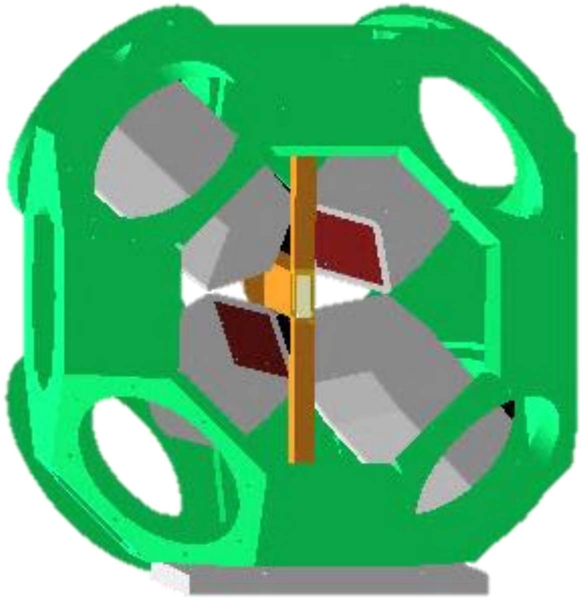
Courtesy of Silvia Bara (KU Leuven), Reinhard Heinke (CERN)

Geant4 Simulations of the HPGe detectors

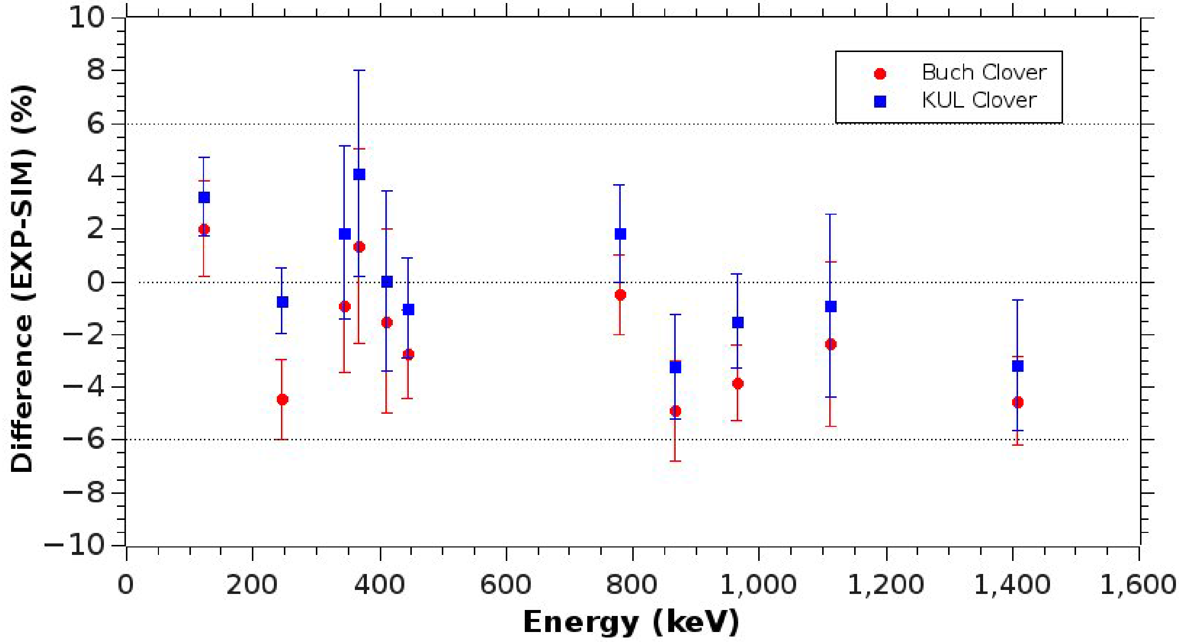
- Previous simulation codes (F. Rotaru, C. Sotty, N. Warr) were fully rewritten (R. Lica, C. Sotty)
- CAD models were imported in the simulation.
- Accuracy is around 95%
- Code still under development to include all ancillary detectors, will be published soon (>2019)



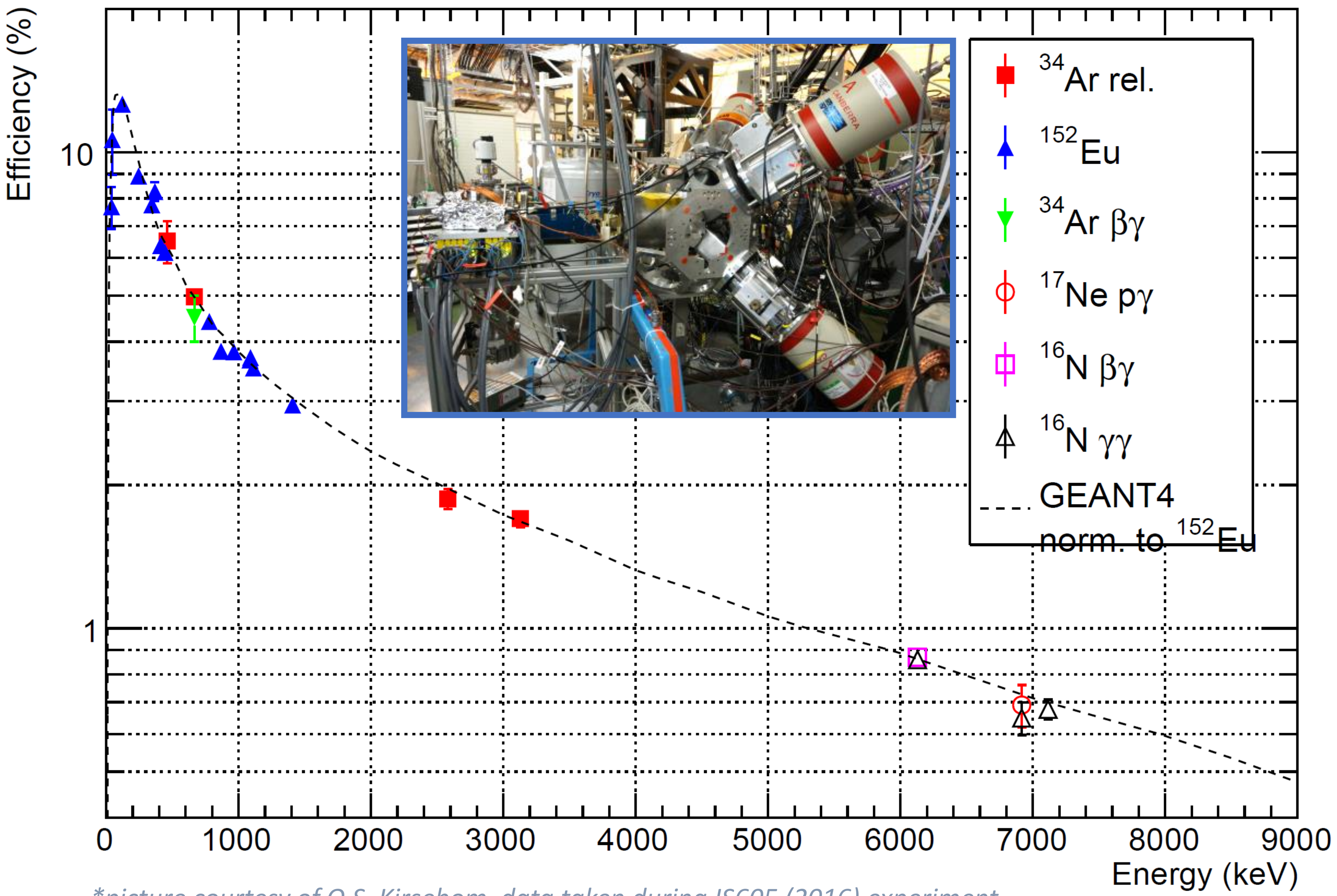




Geometry created using AUTOCAD and imported in Geant4 using CADMesh



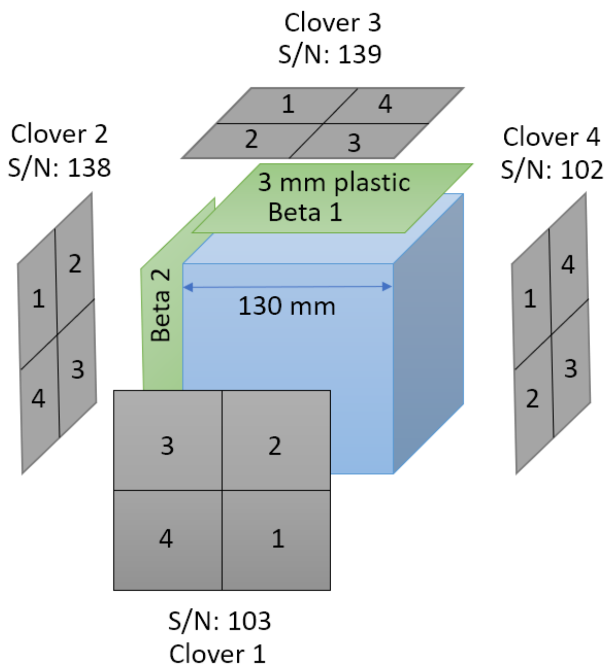
Absolute γ-ray peak detection efficiency (with addback)

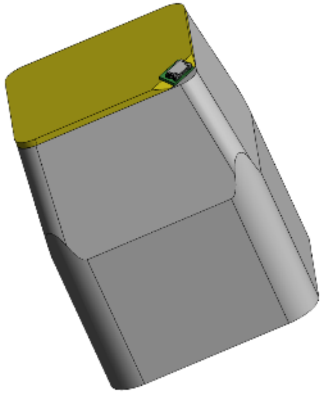


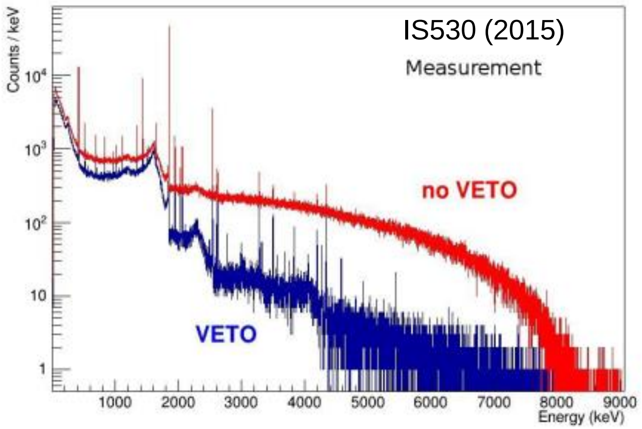
**picture courtesy of O.S. Kirsebom, data taken during IS605 (2016) experiment*

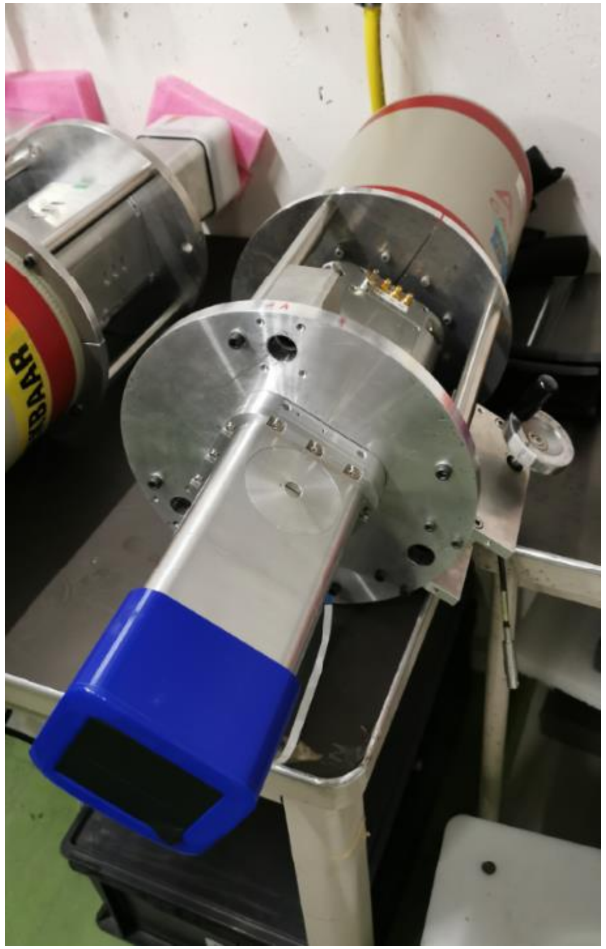
VETO detectors for HPGe

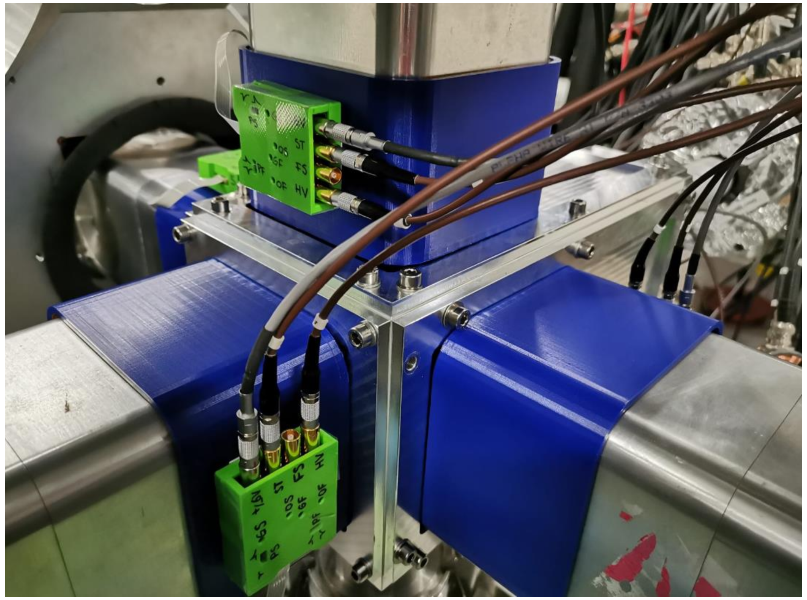
- Plastic scincillators read via SiPM as β-VETO detectors to be placed in front of each HPGe Clover. 20 detectors already ordered.
- (2021) 6 final detectors built, 2 installed during the IS665 experiment and used as both veto and beta detection

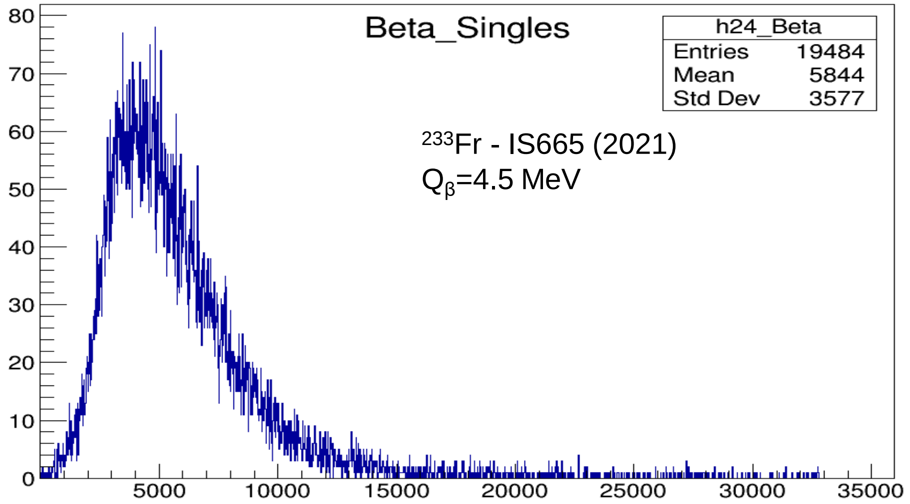


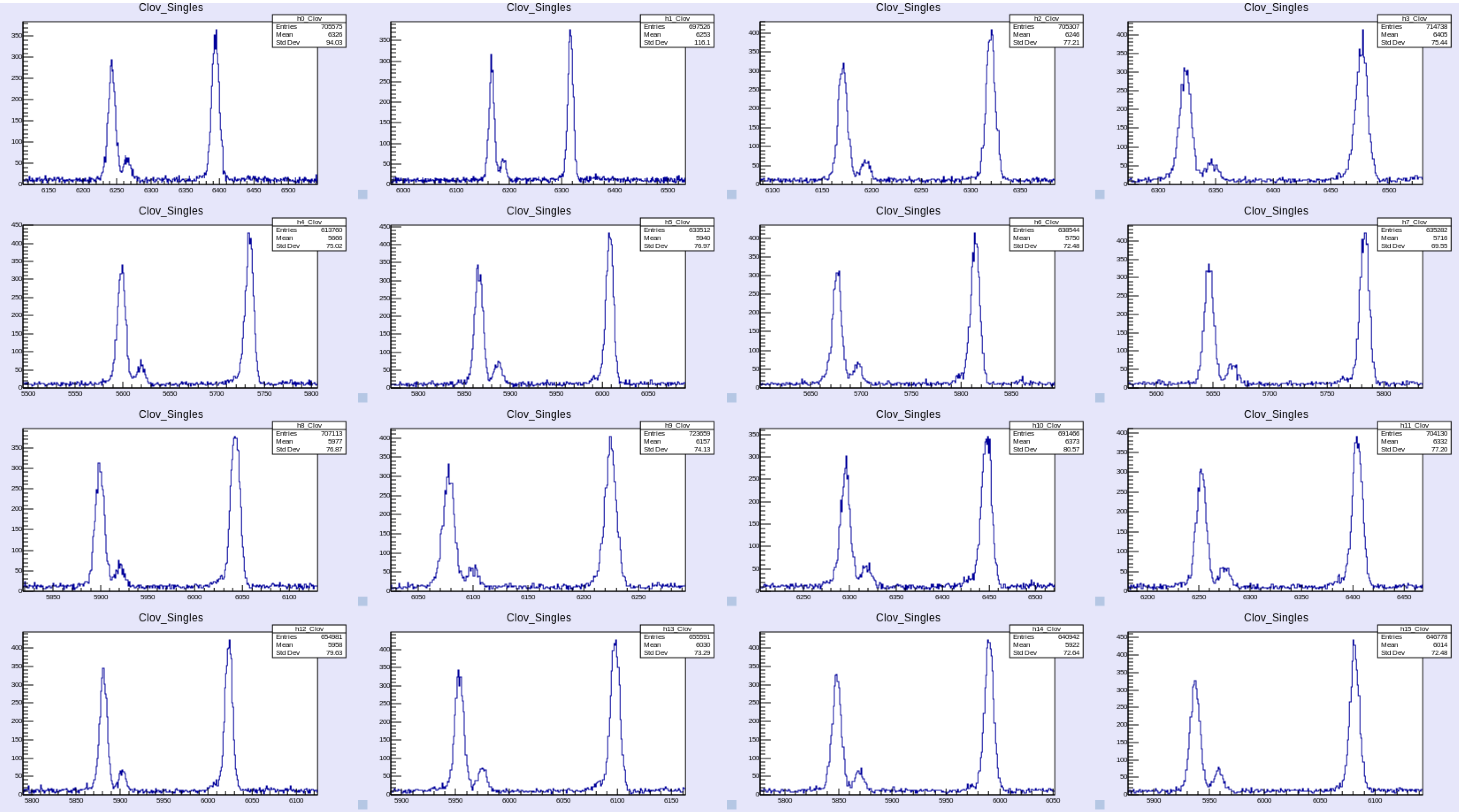








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Std Dev 94.03
Clov_Singles
h1_Clov
Entries 697526
Mean 6253
Std Dev 116.1
Clov_Singles
h2_Clov
Entries 705307
Mean 6246
Std Dev 77.21
Clov_Singles
h3_Clov
Entries 714738
Mean 6405
Std Dev 75.44
Clov_Singles
h4_Clov
Entries 613760
Mean 5666
Std Dev 75.02
Clov_Singles
h5_Clov
Entries 633512
Mean 5940
Std Dev 76.97
Clov_Singles
h6_Clov
Entries 638544
Mean 5750
Std Dev 72.48
Clov_Singles
h7_Clov
Entries 635282
Mean 5716
Std Dev 69.55
Clov_Singles
h8_Clov
Entries 707113
Mean 5977
Std Dev 76.87
Clov_Singles
h9_Clov
Entries 723659
Mean 6157
Std Dev 74.13
Clov_Singles
h10_Clov
Entries 691466
Mean 6373
Std Dev 80.57
Clov_Singles
h11_Clov
Entries 704130
Mean 6332
Std Dev 77.20
Clov_Singles
h12_Clov
Entries 654981
Mean 5958
Std Dev 79.63
Clov_Singles
h13_Clov
Entries 655591
Mean 6030
Std Dev 73.29
Clov_Singles
h14_Clov
Entries 640942
Mean 5922
Std Dev 72.64
Clov_Singles
h15_Clov
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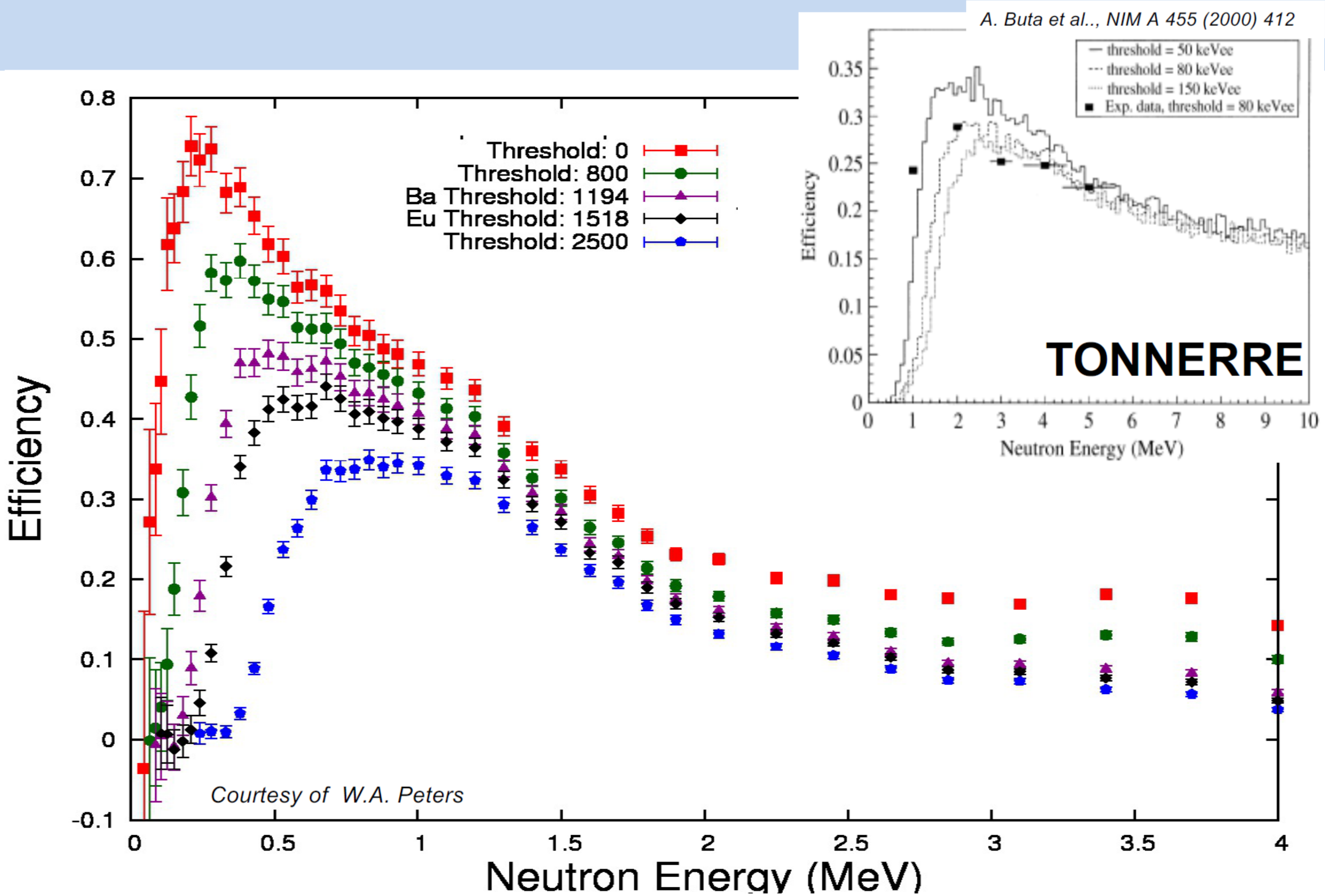
Mean 6014
Std Dev 72.48

Highly improved neutron efficiency



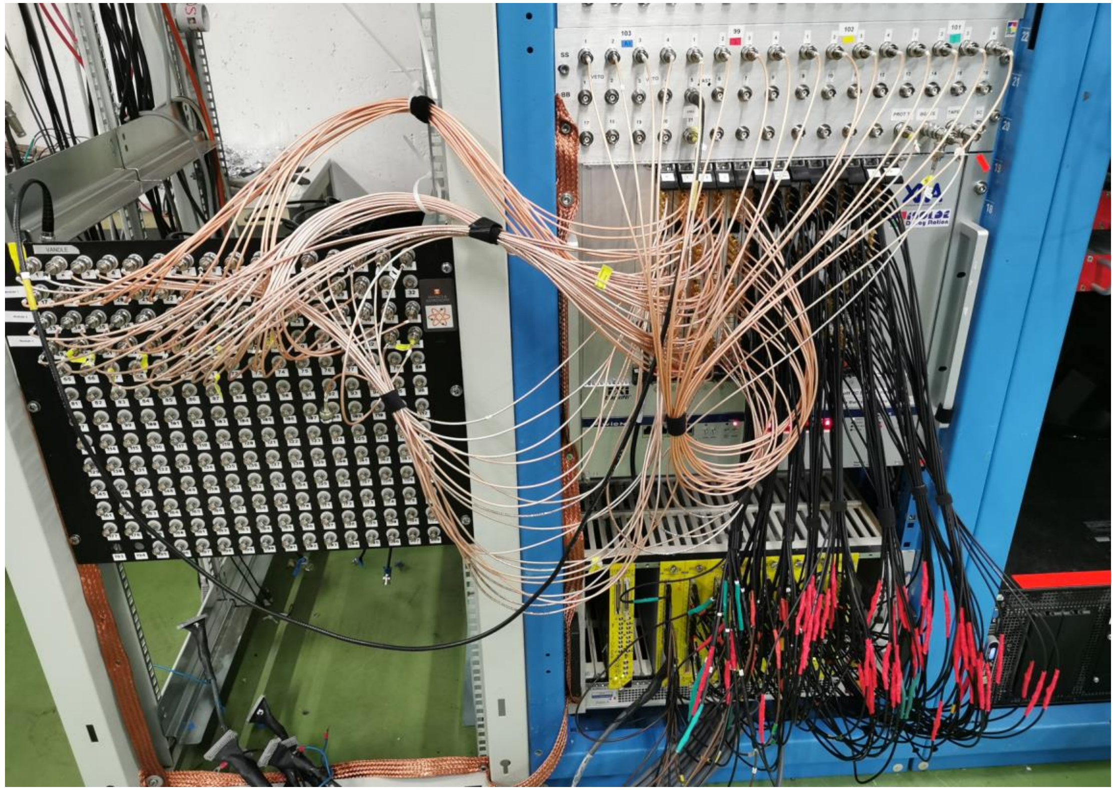
XIA Pixie-16 DAQ

IDS Configuration	Detectors	Total Channels
Particle spectroscopy	4 Clovers + 5 DSSSDs (5 x 32 ch) + 4 PAD (4 x 2 ch) + Logic (6 ch)	**190**
Neutron Spectroscopy (INDiE)	4 Clovers + 26 bars (26 x 2 ch, **traces**) + Beta (2 ch, **traces**) + Logic	**76**
Conversion Electron Spectroscopy	5 Clovers + SPEDE (24 ch) + Beta (1 ch) + Logic	**51**
High beta-gamma efficiency	5-6 Clovers + Beta (2 ch) + Logic	**32**
Fast-timing	4 Clovers (4 x 4 ch) + 2 LaBr + Beta (1 ch) + 3 TAC + Logic	**28**

Current configuration at IDS (2022):

- 13 boards (208 channels) - *250 MHz, 16/ 12 bit capable to handle* ***INDiE, 4 Clovers, 4 DSSSD, 4 Plastic***
- *1 extra 500 MHz board for testing digital fast-timing*

Permanent IDS DAQ (64 ch)
4 x PIXIE-16 250 MHz, 16 bit ADC



Available software:
https://github.com/rlica/xia4ids
https://github.com/pixie16/paass