The ISOLDE Decay Station: recent activities and perspectives

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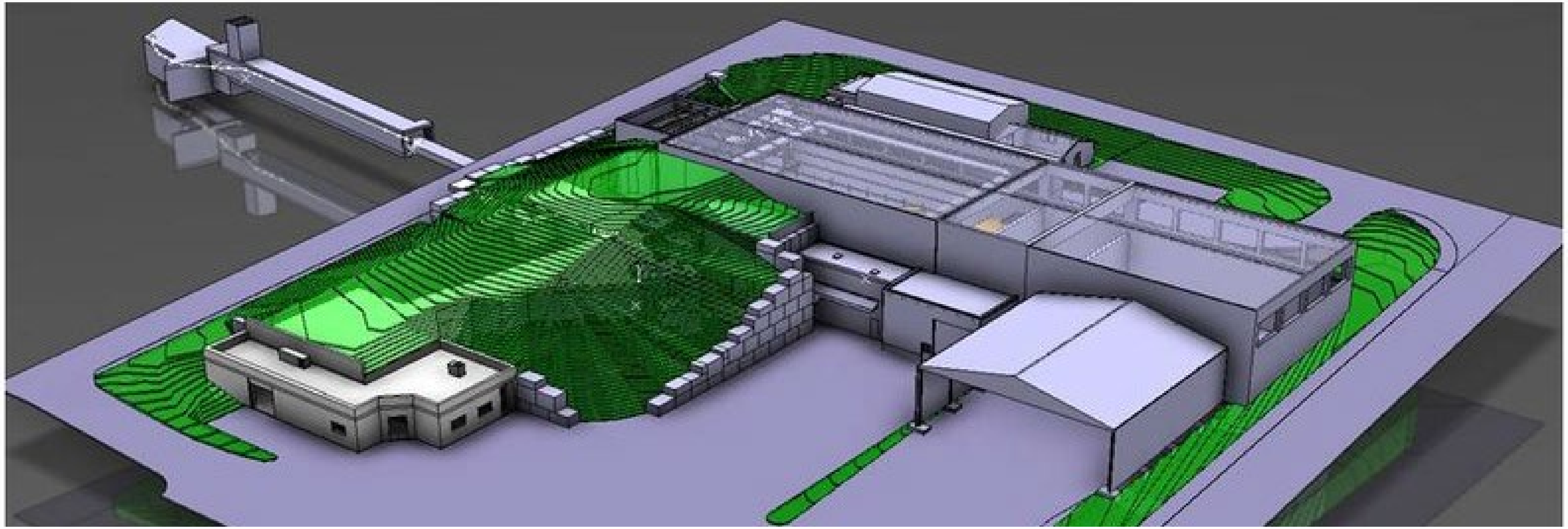
IFIN-HH, Romania

13 October 2023, NUSTAR Week, Magurele, Romania



The ISOLDE-CERN Facility

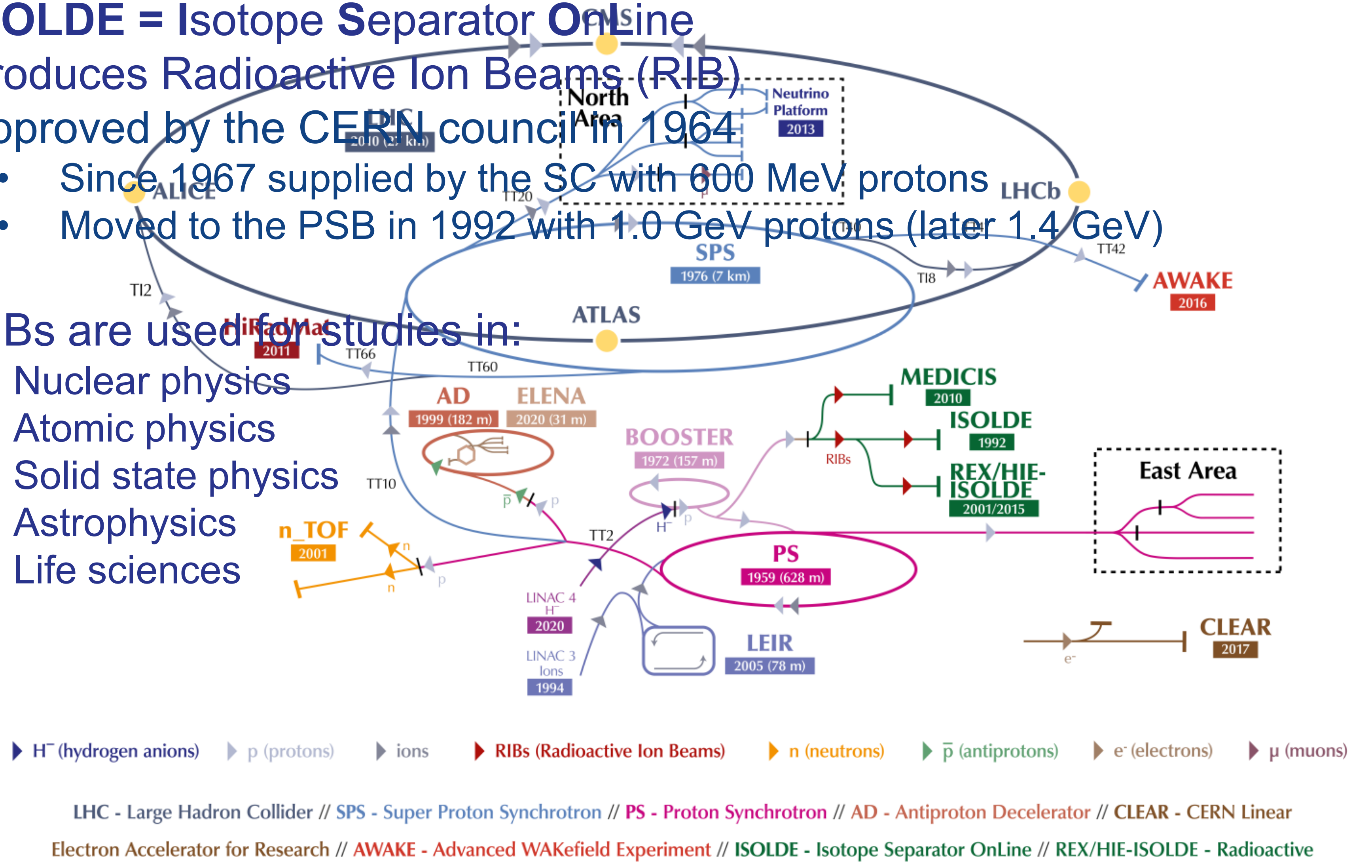
- a brief overview -

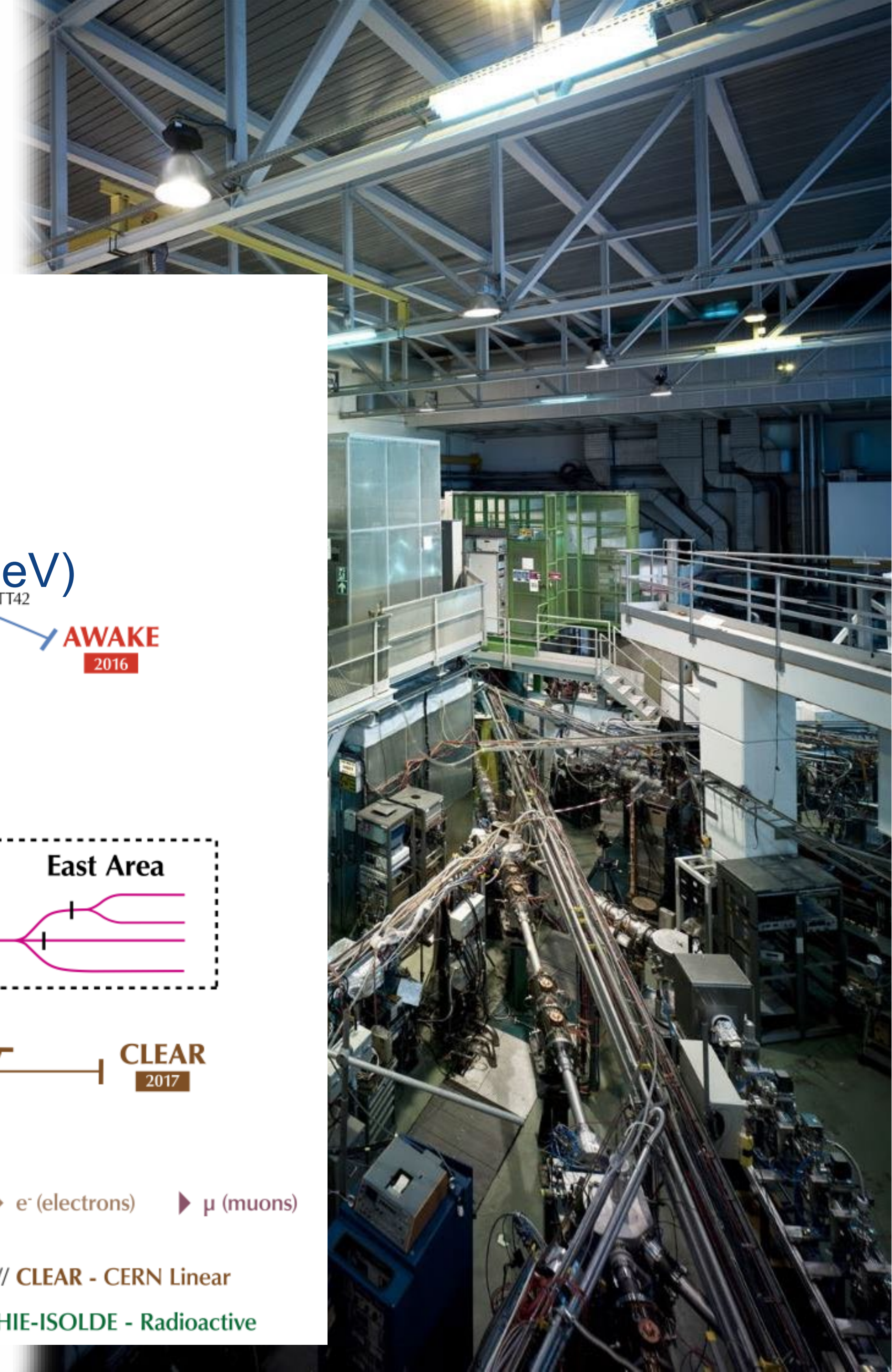
Slides courtesy of: **João Pedro Ramos**, CERN A&T Sector Seminar, 2017; **Reinhard Heinke**, ISOLDE Workshop 2022; **Sean Freeman**, NUPECC TWG6, 2023

CERN

- **ISOLDE = I**sotope **S**eparator **O**n**L**ine
- Produces Radioactive Ion Beams (RIB)
- Approved by the CERN council in 1964
  - Since 1967 supplied by the SC with 600 MeV protons
  - Moved to the PSB in 1992 with 1.0 GeV protons (later 1.4 GeV)

- RIBs are used for studies in:
  - Nuclear physics
  - Atomic physics
  - Solid state physics
  - Astrophysics
  - Life sciences





CERN

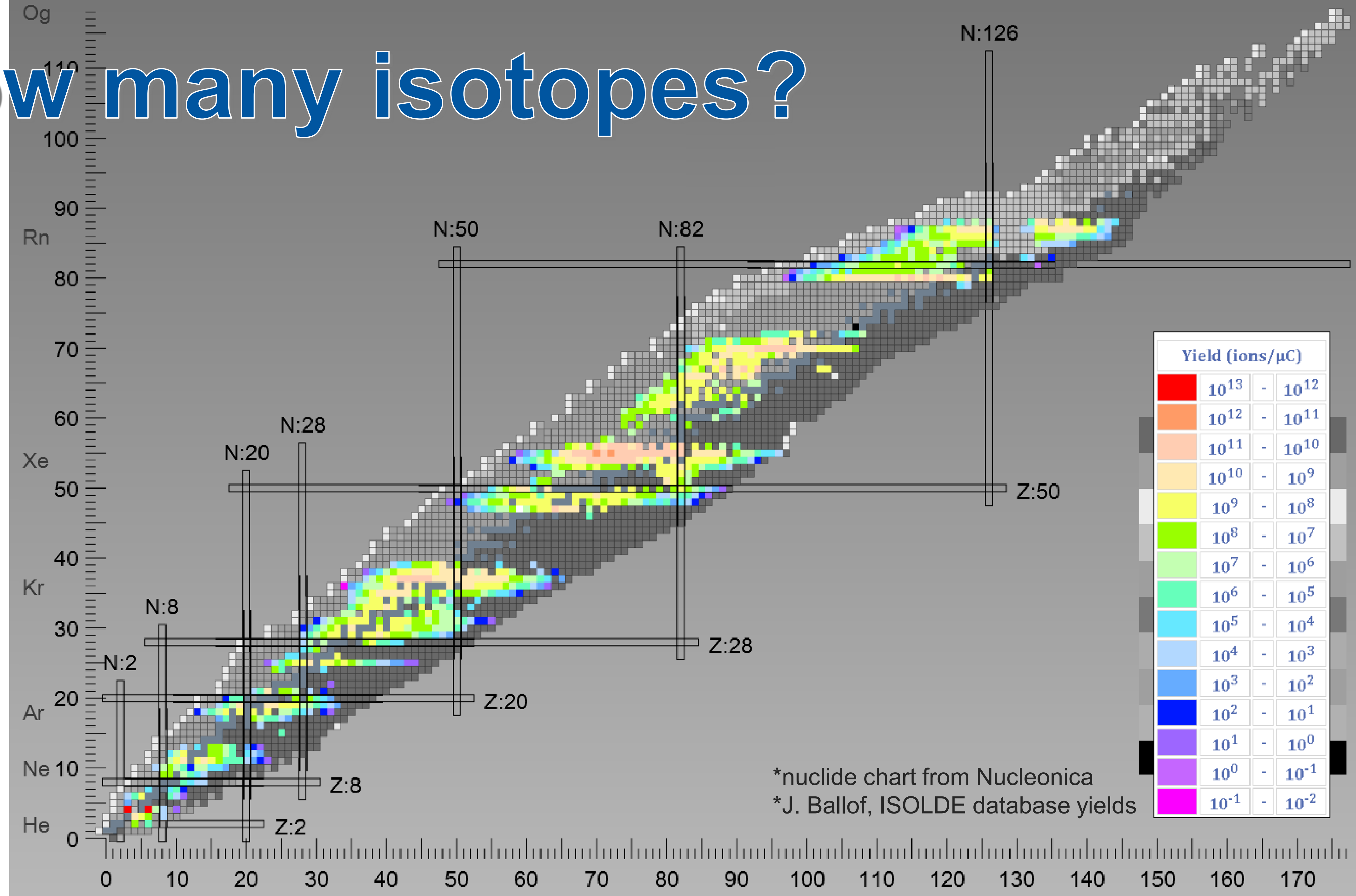
How many isotopes?

Predicted
~6000

Discovered
~3000

ISOLDE
~1000

Elements
74
$t_{1/2}$
>tens of ms



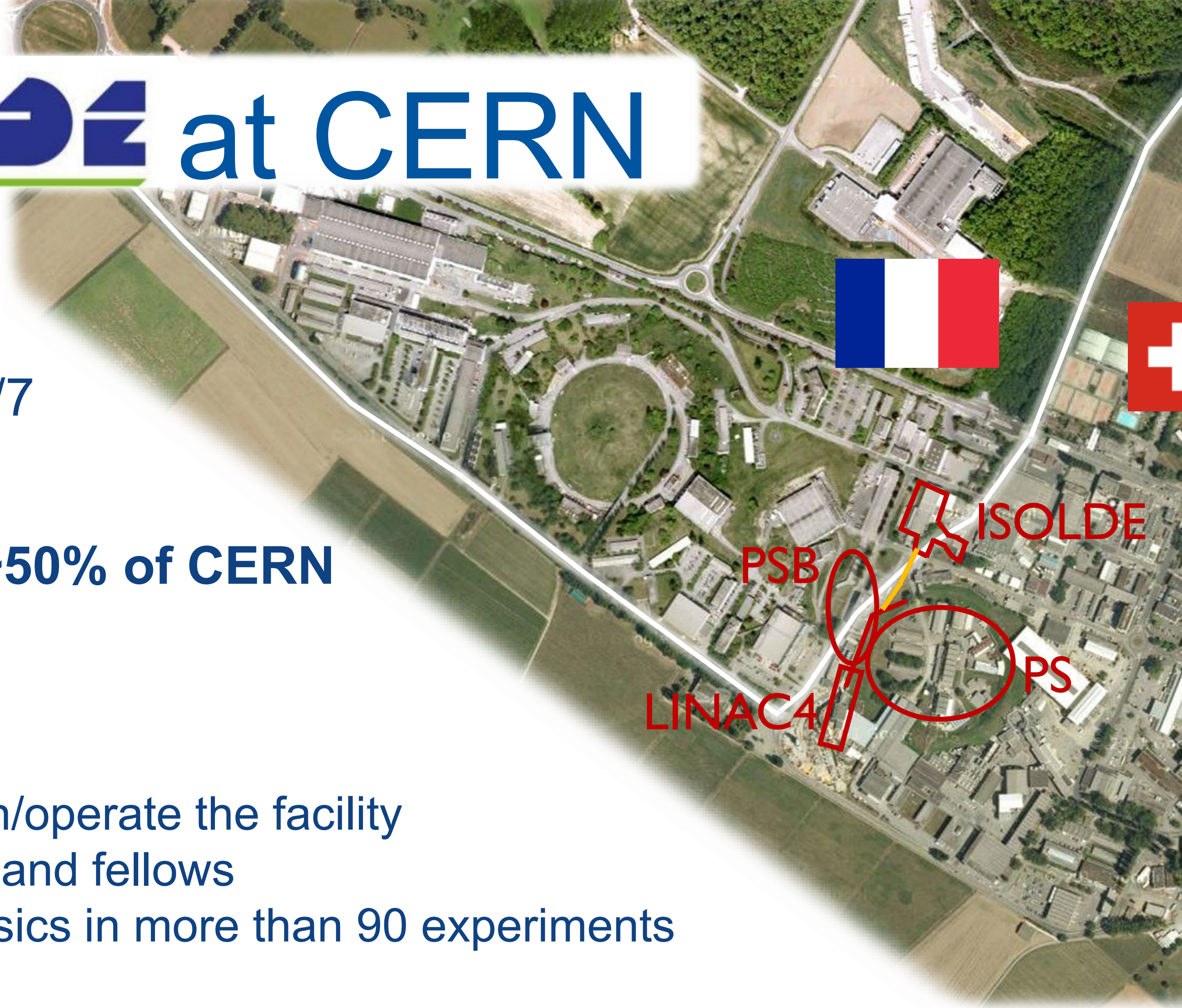
*nuclide chart from Nucleonica
*J. Ballof, ISOLDE database yields

CERN

ISOLDE at CERN

Operates ~8 months/year, 24/7

ISOLDE takes ~50% of CERN protons



~50 staff – maintain/operate the facility

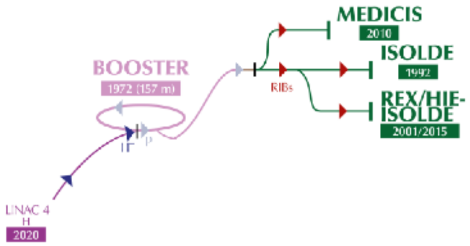
- A few students and fellows

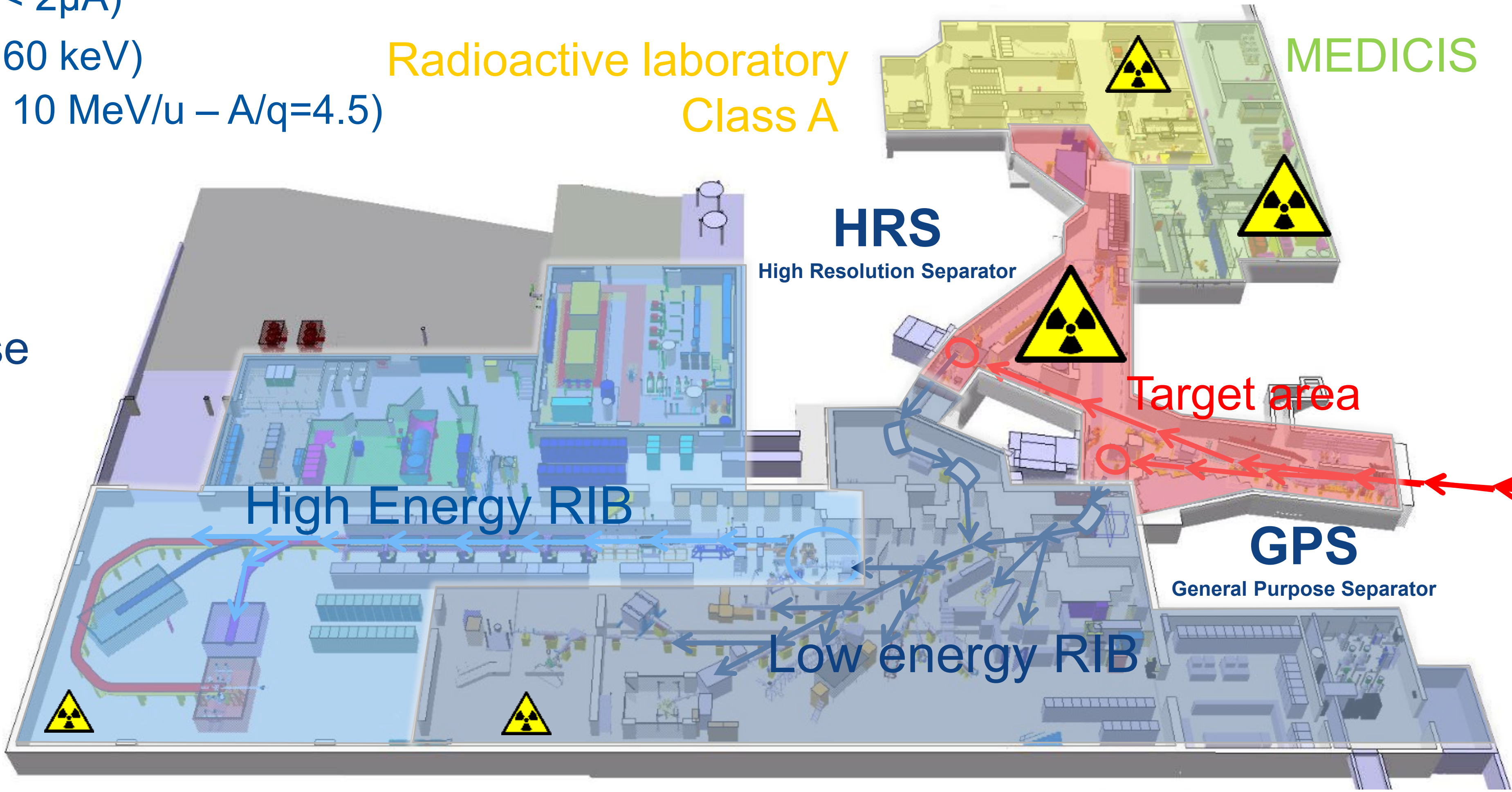
~450 users for physics in more than 90 experiments

ISOLDE Facility

- Protons (1.4 – 2.0 GeV, < 2μA)
- Low energy RIBs (up to 60 keV)
- High energy RIBs (up to 10 MeV/u – A/q=4.5)

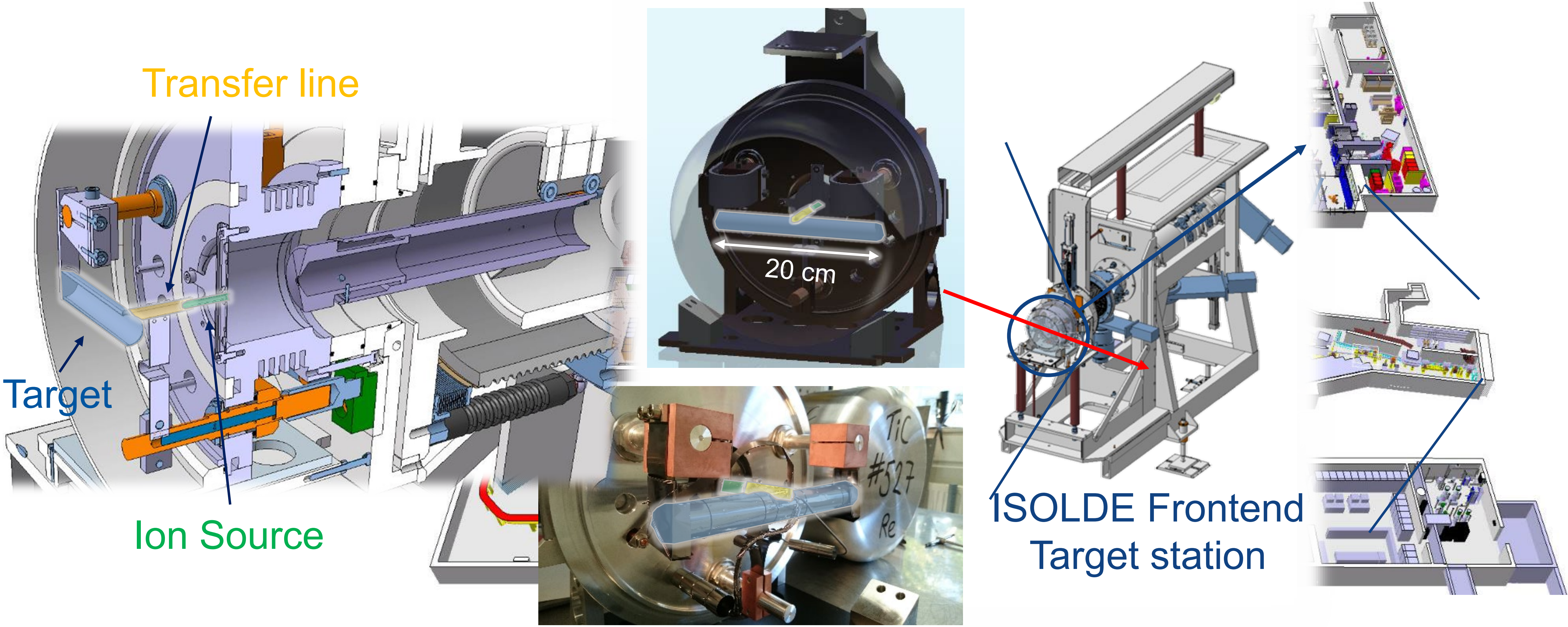
Pulsed protons (1.2 s)
1.4 GeV
3.3×10^{13} protons per pulse





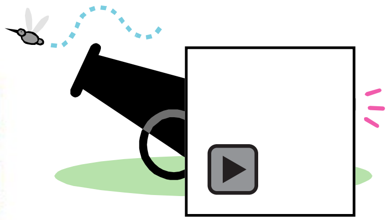
*picture courtesy of M. Delonca

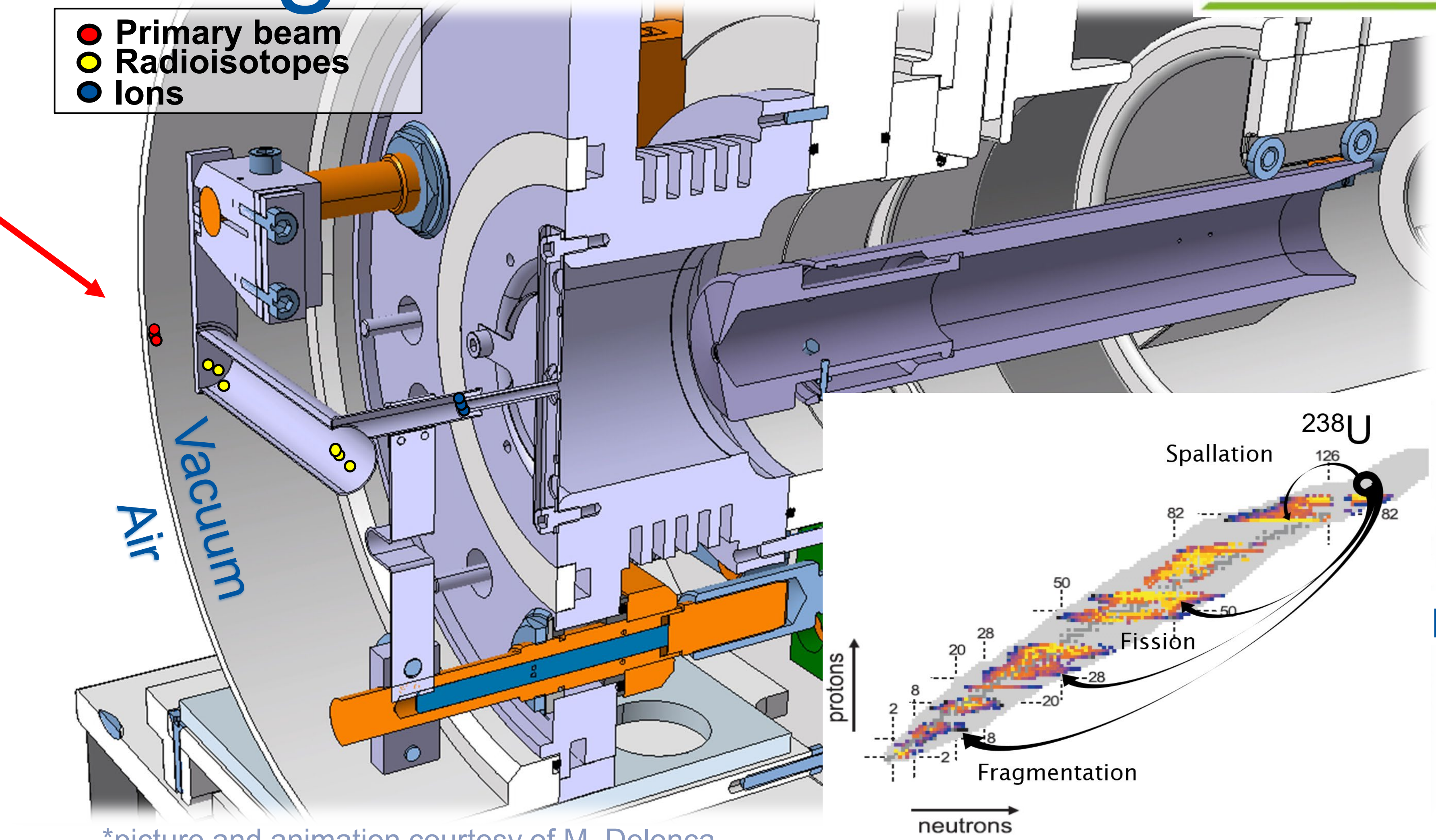
Target Unit – Heart of ISOLDE



*pictures courtesy of M. Delonca and J. Montano

Target Unit – Heart of ISOLDE



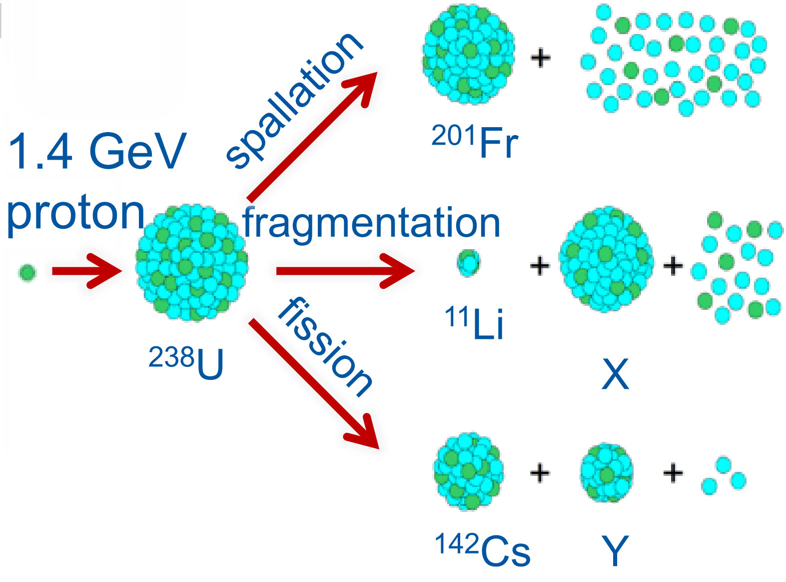


*picture and animation courtesy of M. Delonca

Beam power

- 2.8 kW in average
- 1.2 GW (pulse length 2.3 μs)
  - ~10% deposited

What is the sound of proton impact on target?



ISOLDE Consolidation, Improvements and Expansion

LS3 = December 2025 to Spring 2027 (for proton injectors).

Mid-term goals (up to and including LS3)

- Nanomaterial-based target lab coming online.
- Front End & RILIS laser ionisation consolidation.
- Post-accelerator consolidation and cryo improvements.
- **New proton beam dumps** to modern radiological standards and to receive **higher energy protons at higher intensity**, with several infrastructure improvements to target areas.
- Upgrade of line from PS Booster to deliver **2-GeV** protons: increased yield of fission fragments by ~1.4, fragmentation products by ~ ×2 − 5, and exotic spallation products by >×6.
- Increased proton currents (**up to ×3**), enabled by new beam dumps, improves these factors further.
- Investigate **parallel RIB operation** with GPS and HRS.
- Upgrade of ventilation and improve fire safety.

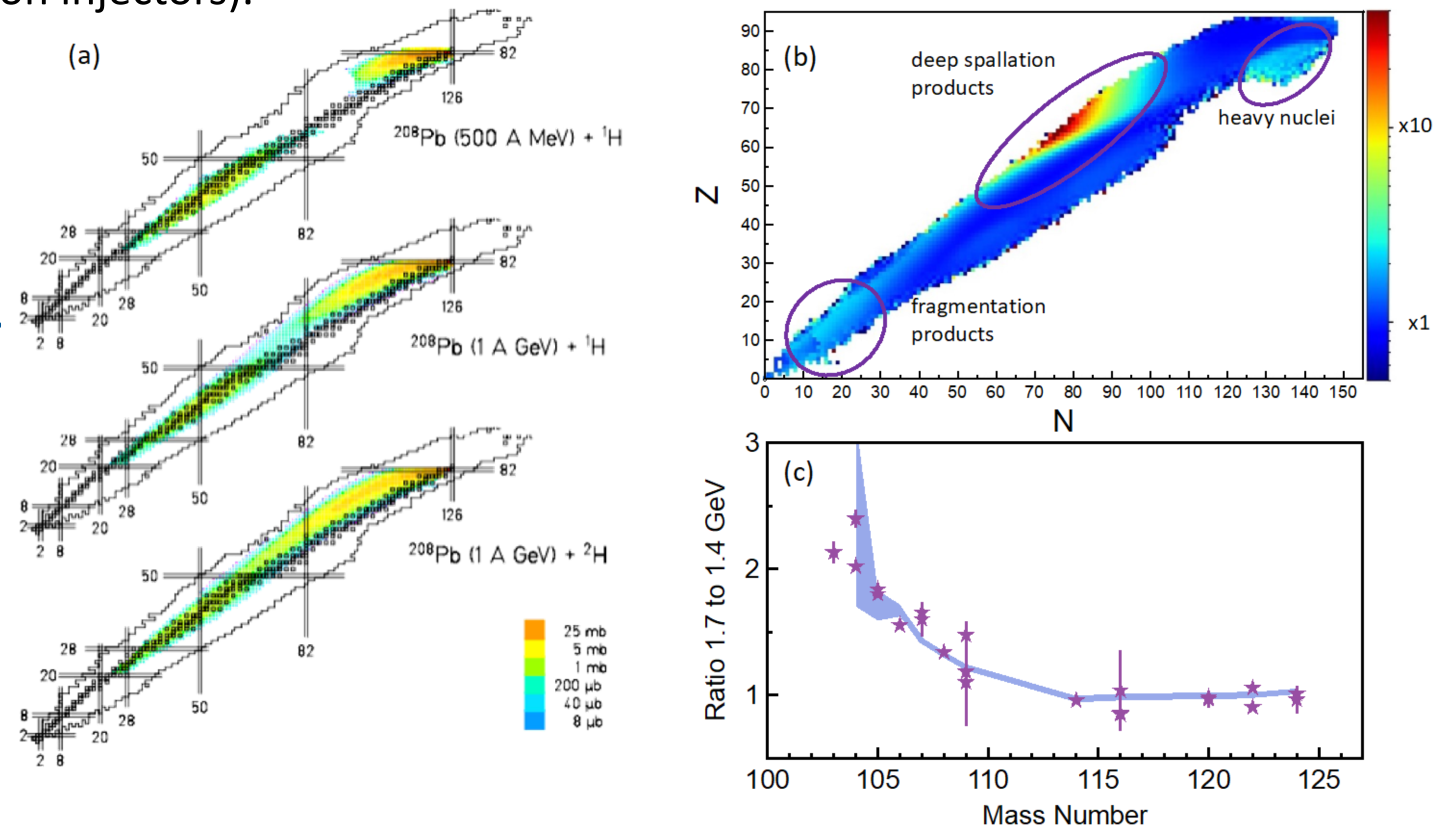


Figure 1: (a) Figure taken from Ref. 14 showing experimental cross sections in the spallation of 208Pb, (b) FLUKA simulations for a UCx target showing the ratio of production yield at 2 GeV to that at 1.4 GeV (improvements due to increased proton intensity are additional) and (c) measurements of In isotopic yield ratios at 1.7 GeV to 1.4 GeV compared to FLUKA predictions (blue band).

Improved RIB yield:

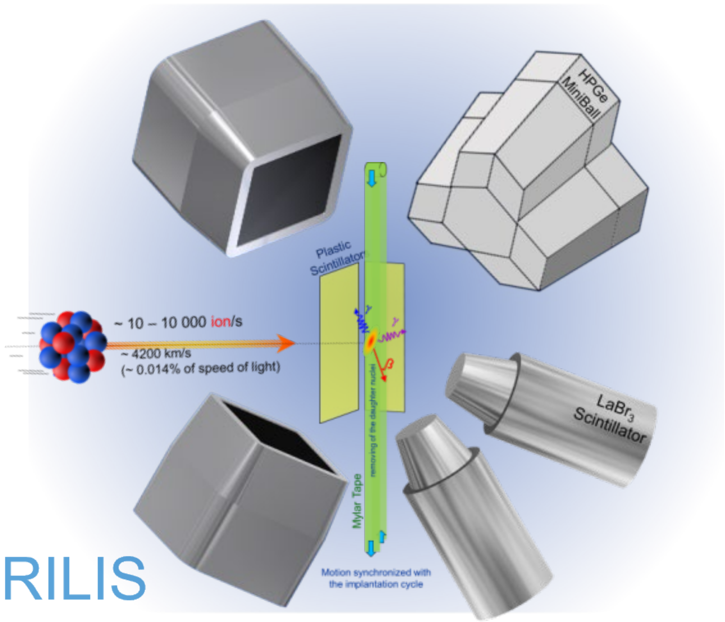
1. Increased capacity – more experiments.
2. Increased statistics – more precision.
3. Increased capability – measurements on new isotopes.

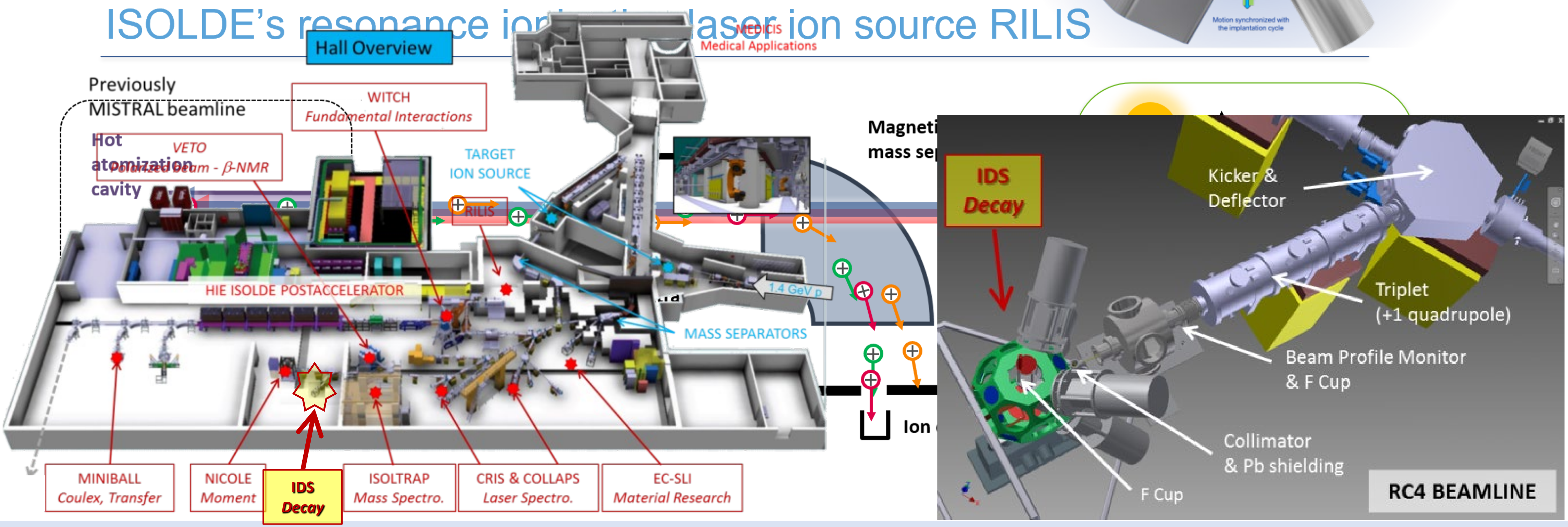
IDS Collaboration

The ISOLDE Decay Station

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** (6 permanent Clovers + others)
    - **Ancillary detectors** ($LaBr_3$, plastic scintillator, silicon, neutron)
    - **Tape station**
    - **In-Source Laser Spectroscopy Studies using RILIS** (since 2017)





ISOLDE Decay Station Collaboration

Collaborating institutes

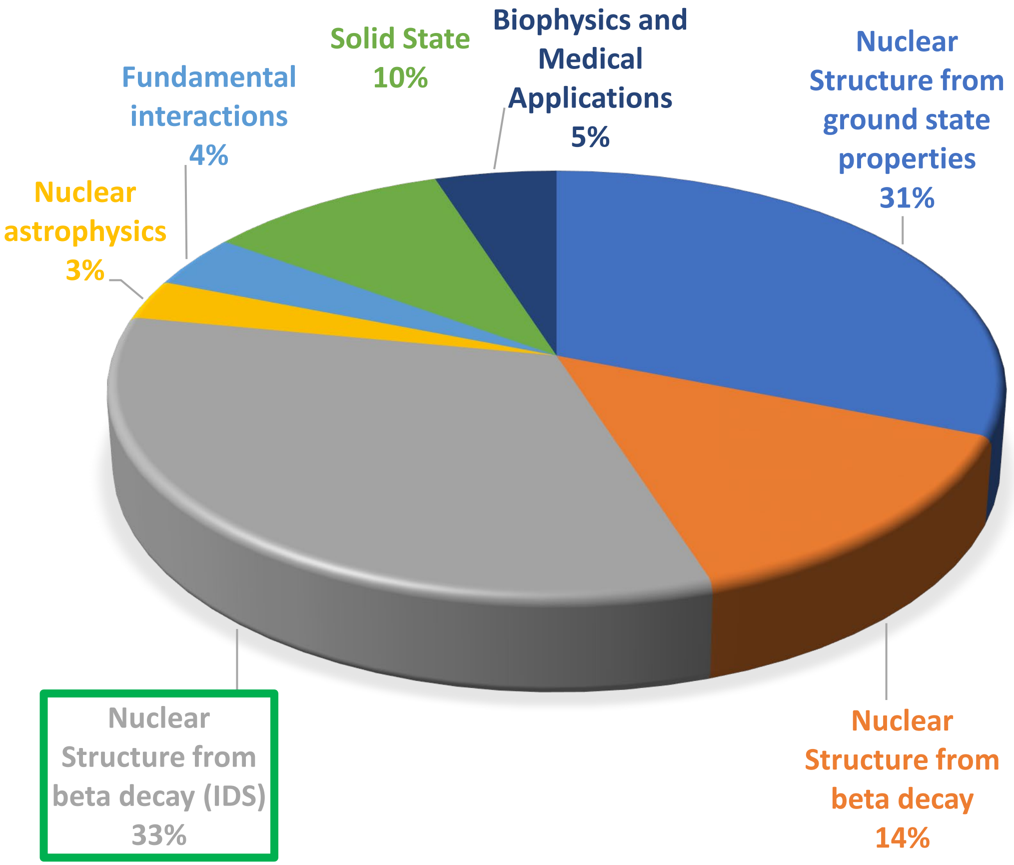
- Belgium (KU Leuven)
- Denmark (Aarhus University, Department of Physics and Astronomy)
- Finland (University of Jyväskylä)
- Germany (Institut für Kernphysik - Universität zu Köln)
- Italy (Università degli Studi e INFN Milano)
- Poland (Faculty of Physics, University of Warsaw)
- Romania (IFIN-HH 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.

Spokespersons:
Piet Van Duppen, KU Leuven, Belgium (2013 – 2018)
Razvan Lica, IFIN-HH, Romania (2018 – 2022)
James Cubiss, Uni. York, UK (2022 – present)

FIRST INSTALLATION OF IDS 2014

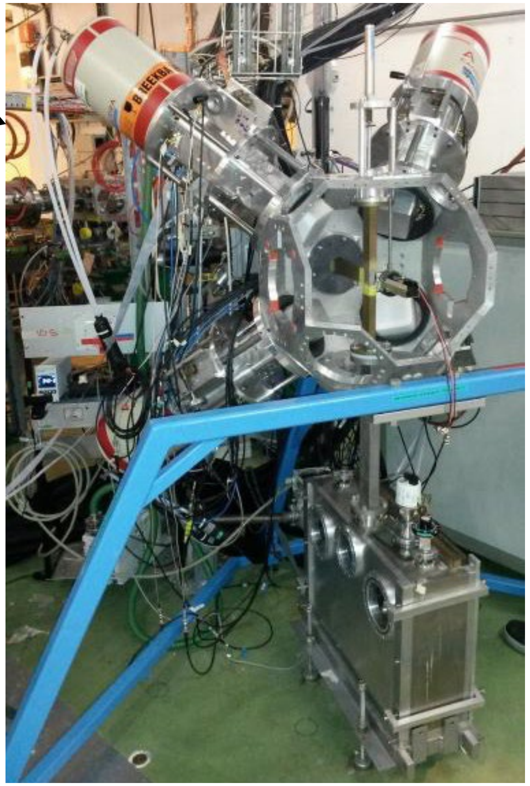
ISOLDE BEAMTIME DISTRIBUTION 2015



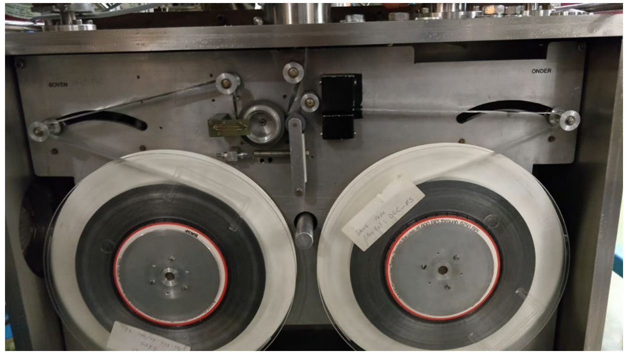
IDS in 2015

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



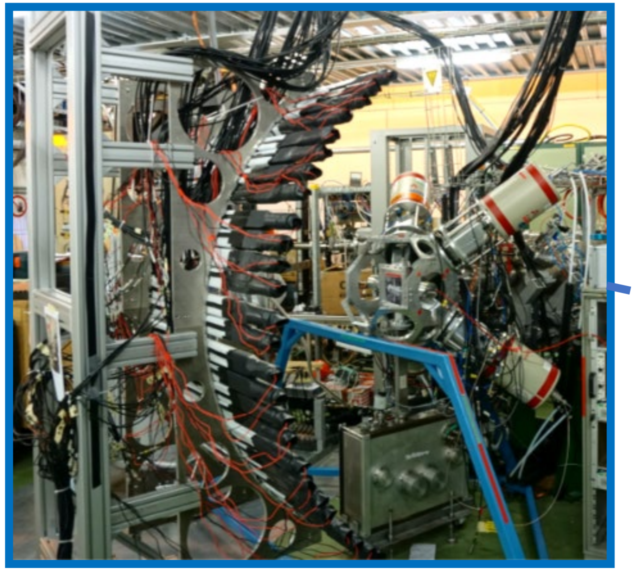
Tape station (KU Leuven)
- Aluminized mylar tape
- Fully automated system
- Can be integrated with ISOLDE

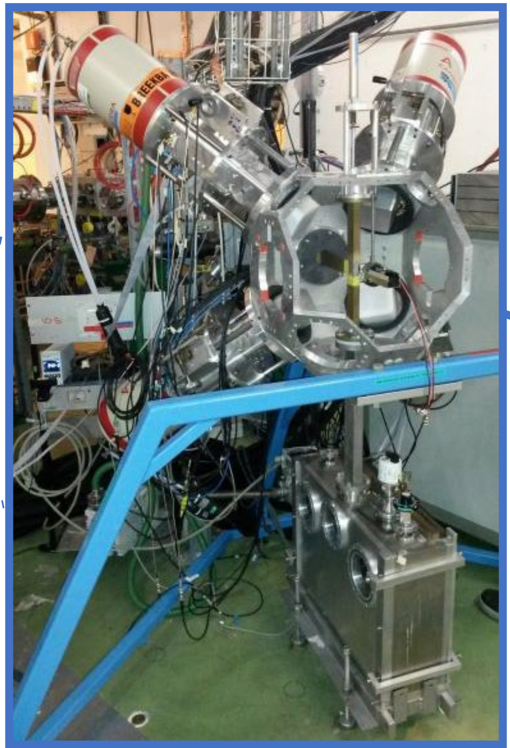


Digital DAQ
NUTAQ VHS-ADC (STFC, JYFL)
- 3 x 16 channels, 100 MHz, 14-bit ADC (virtex4 FPGA)
- MIDAS acquisition software

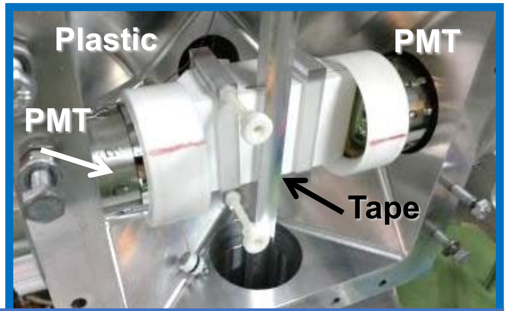
ISOLDE Decay Station 2014-2022

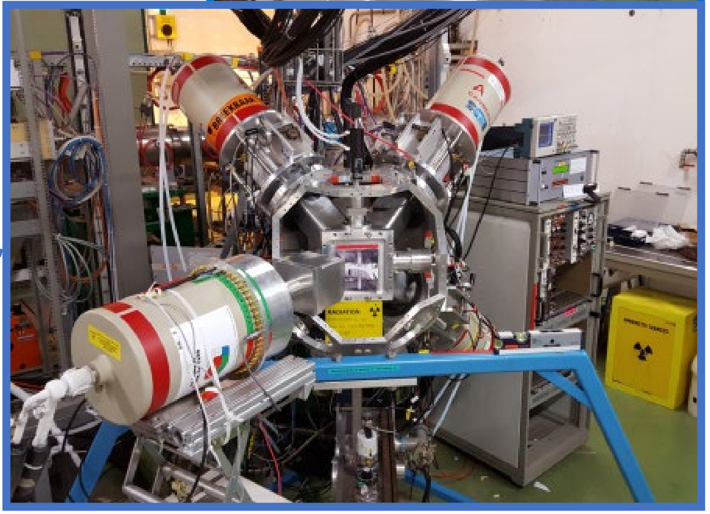
Neutron Spectroscopy



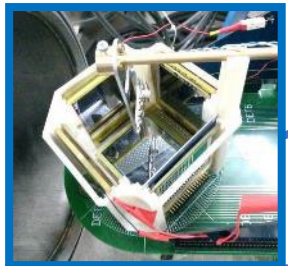


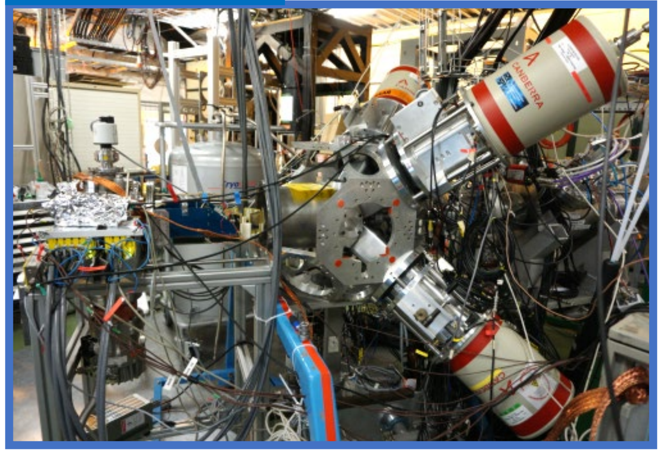
High beta-gamma efficiency



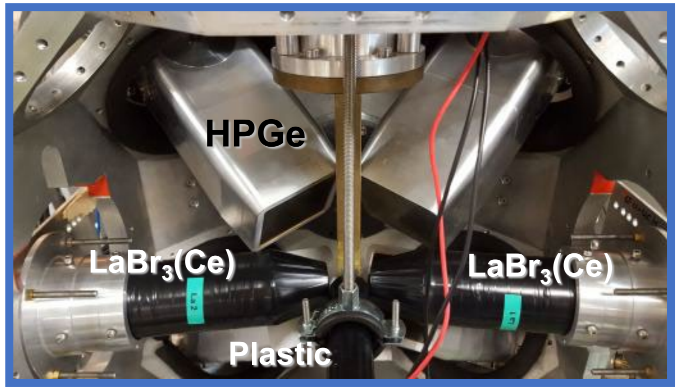


Particle Spectroscopy

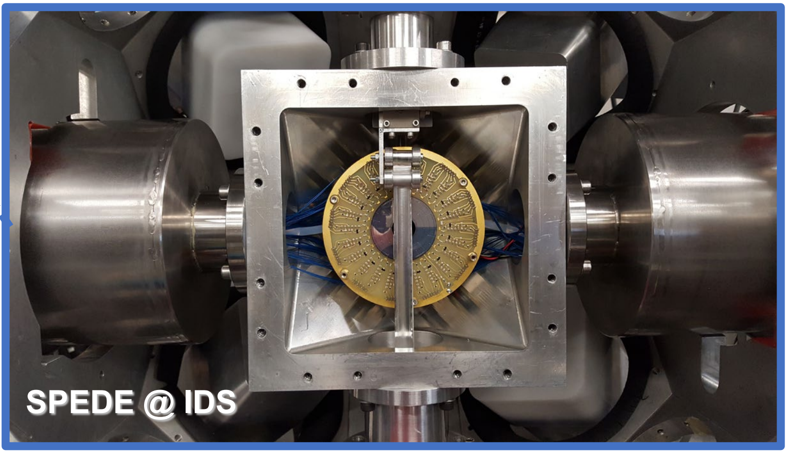




Fast-timing studies



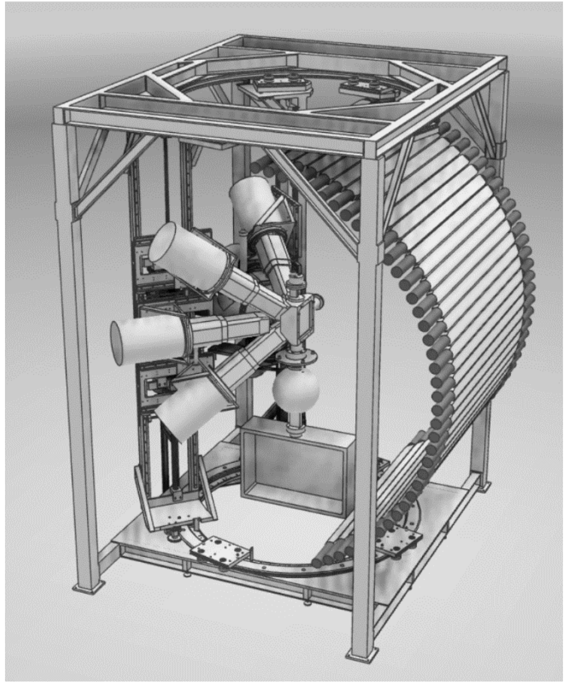
Conversion Electron Spectroscopy



IDS Upgrades during CERN LS2 (2019 – 2021)

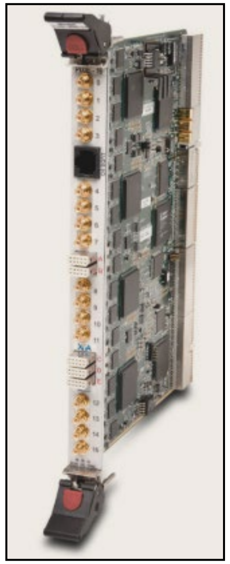
New Support structure

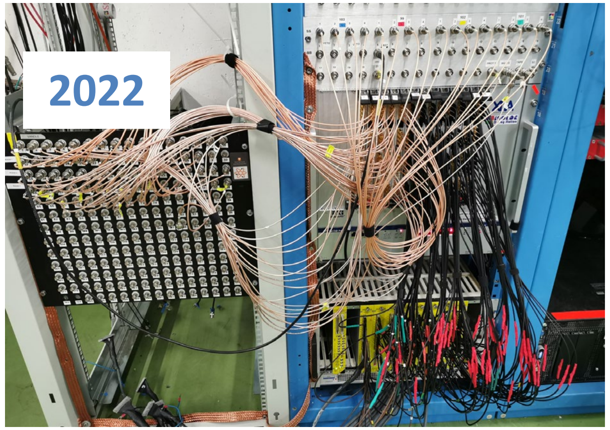
- 2021: finalized the design
- December 2022: installation



New DAQ

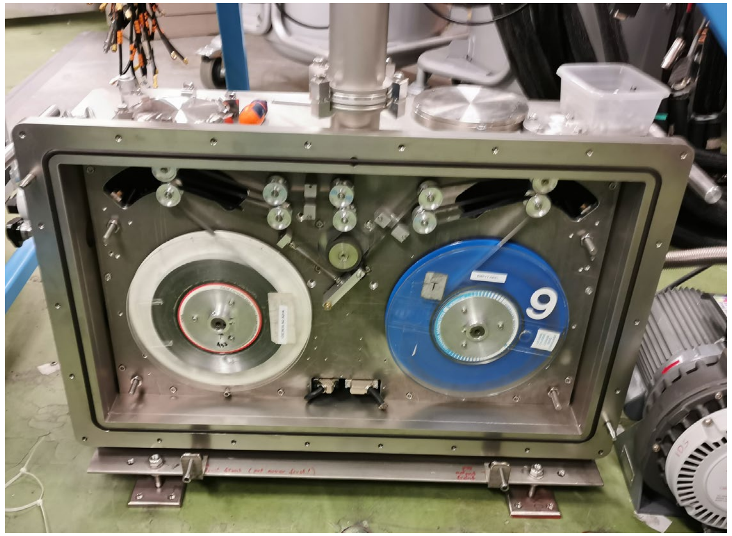
XIA PIXIE-16, 250 MHz, 12-16 bit ADC, 208 ch/crate (13 x 16)



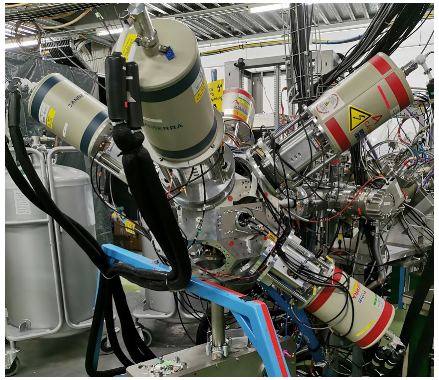


New Tapestation

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



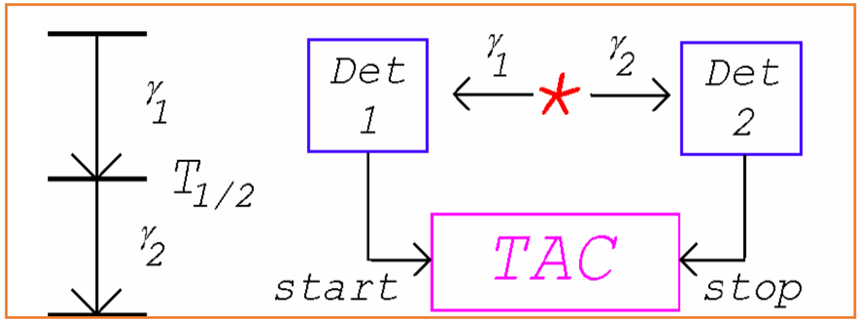
2 new Clover detectors added to the permanent setup

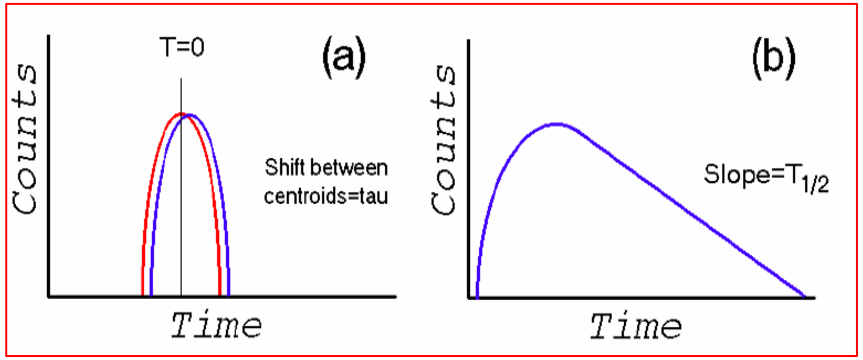


1. Fast-timing studies

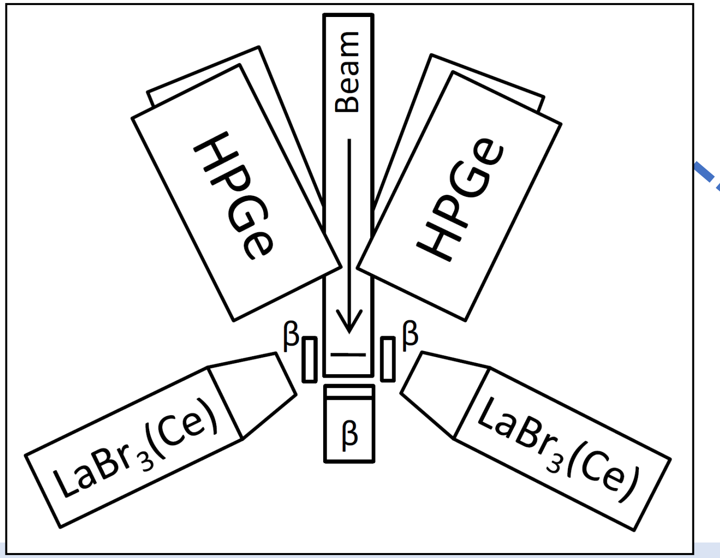
- Well established technique at IDS since 2014 [1,2,3,4, …]
- Detection system comprising of:
  - 4 Clover HPGe - 7% abs. eff. at 500keV
  - 2 $LaBr_3$(Ce) - 3% abs. eff. at 500keV
  - 1 Plastic Scintillator - 20% abs. eff.

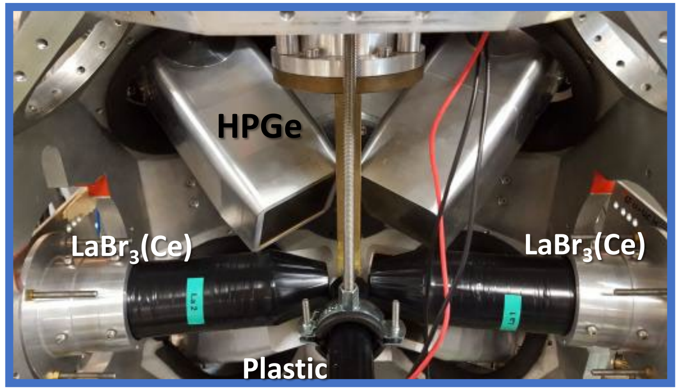
[1] R. Lica et al., Phys. Rev. C 93, 044303 (2016).
[2] R. Lica et al., J. Phys. G 44, 054002 (2017).
[3] L.M. Fraile, J. Phys. G 44, 094004 (2017).
[4] R. Lica et al., Phys. Rev. C 97, 024305 (2018).





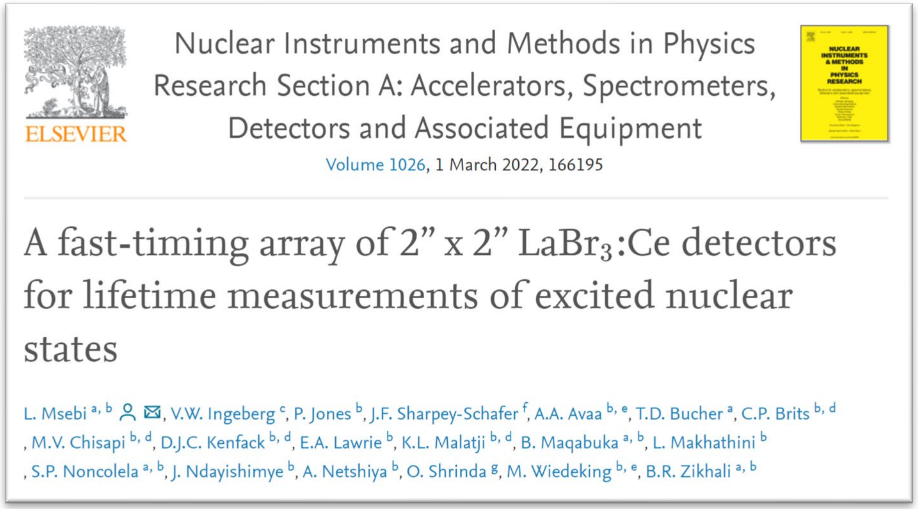
Ranges:
Centroid shift method: - **10 ps - 100 ps**
Slope method - **50 ps - 50 ns** (or longer)
[H. Mach et al. NIM A 280, 49 (1989)]





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

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

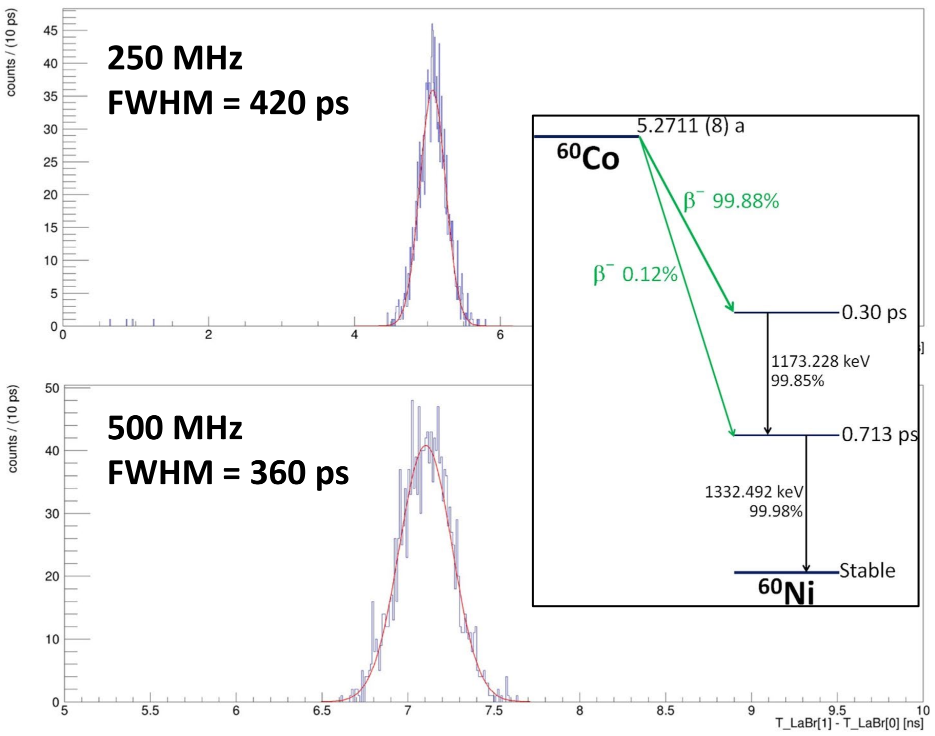


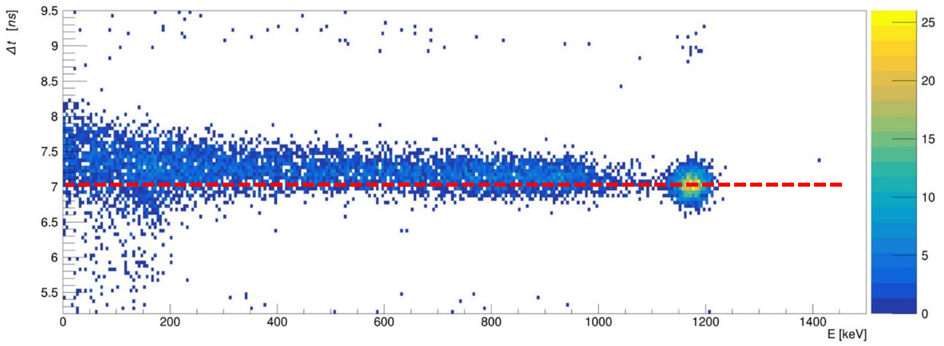
- Current limit of an **analog** system for 1.5" $LaBr_3$(Ce) detectors: FWHM = 155 ps
- Best result achieved offline by a **digital** system (2 GHz): FWHM = 140 ps

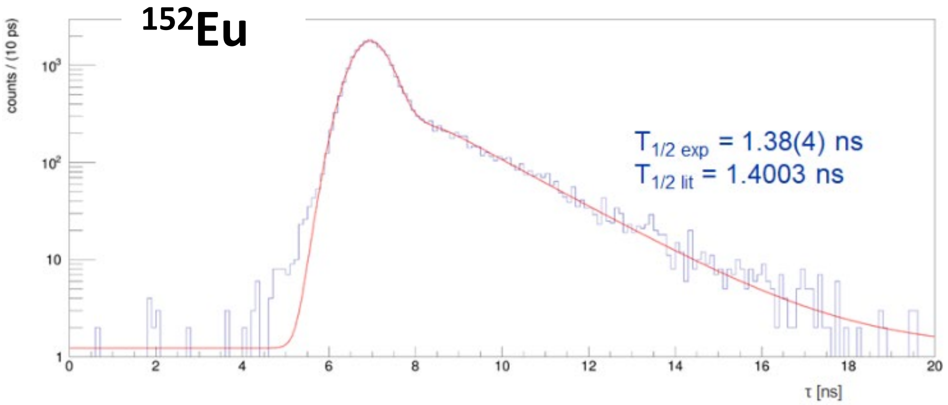
  V. Sanchez-Tembleque, V. Vedia, L.M. Fraile, S. Ritt, J.M. Udias, NIM A 927 54-62 (2019)
- Online digital fast-timing for 2" $LaBr_3$(Ce) with a 500MHz module: FWHM = 320 - 400 ps

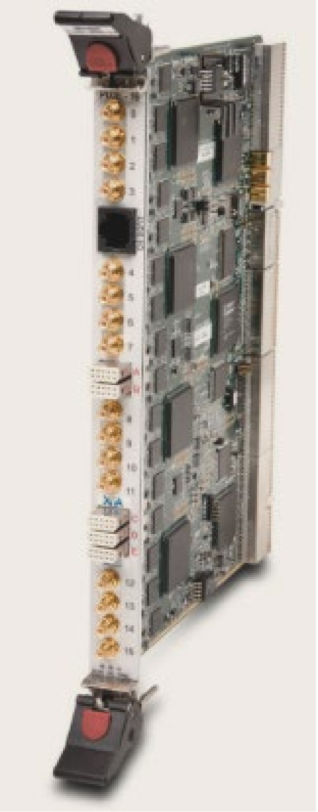
  L. Msebi, V.W. Ingeberg, P. Jones et al., NIM A 1026 166195 (2022)

Confirmed at IDS (Nov 2022)



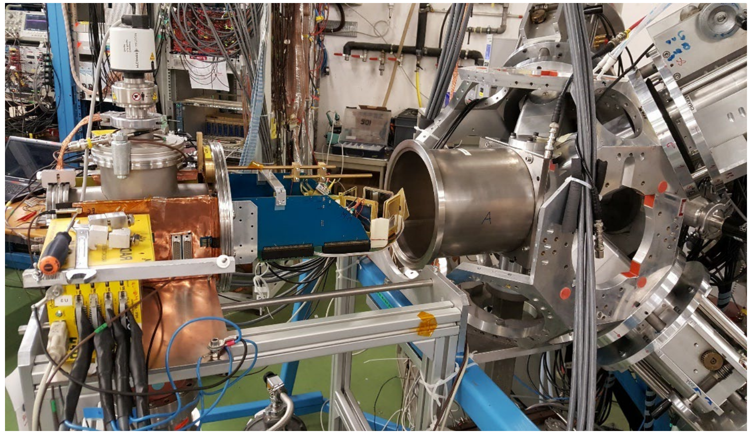


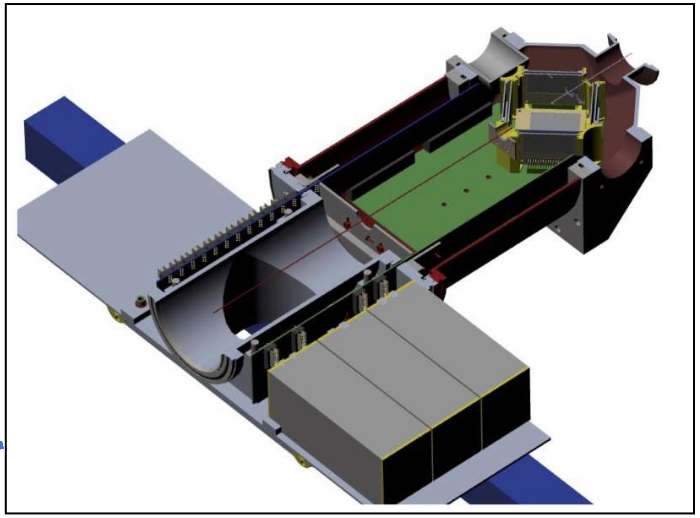


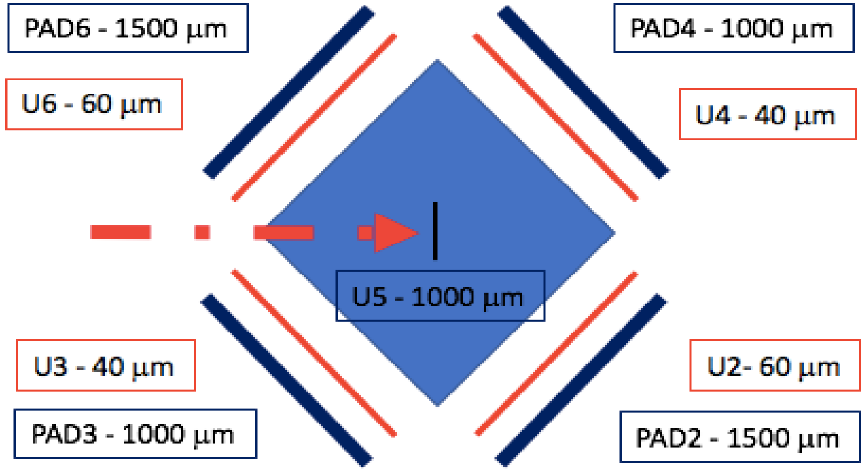


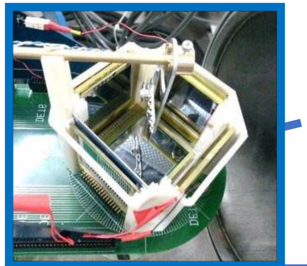
2. Particle Spectroscopy

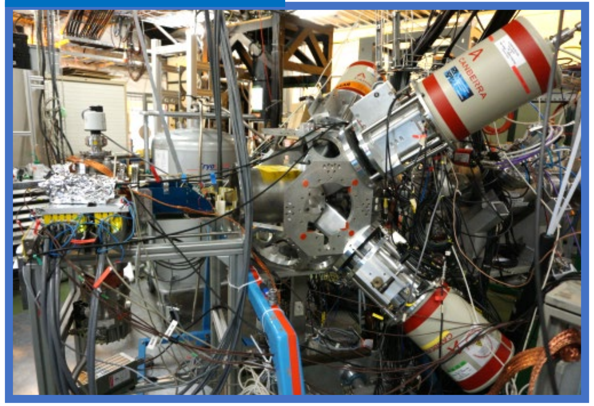
ISOLDE Decay Station + MAGISOL











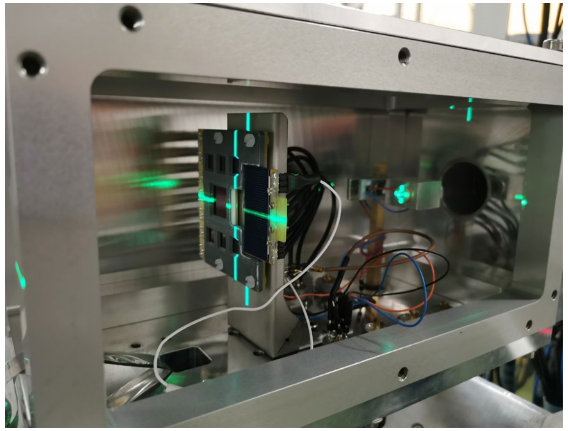
- 4 HPGe Clover detectors + Si box (5 DSSSD's, 4 Pad's)
- Beam implanted on ^{12}C foil or tape

(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)

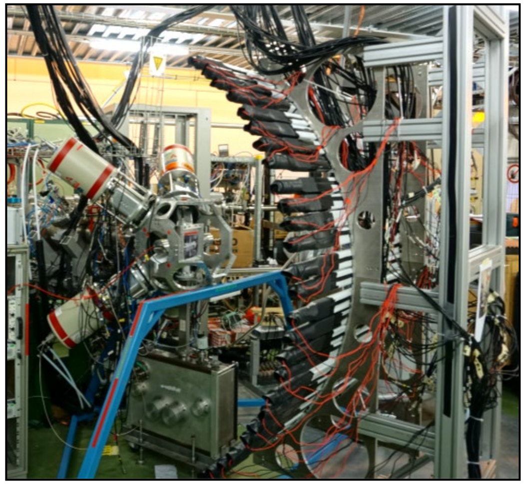
(2021) XIA Pixie-16 handling both particle and gamma detectors

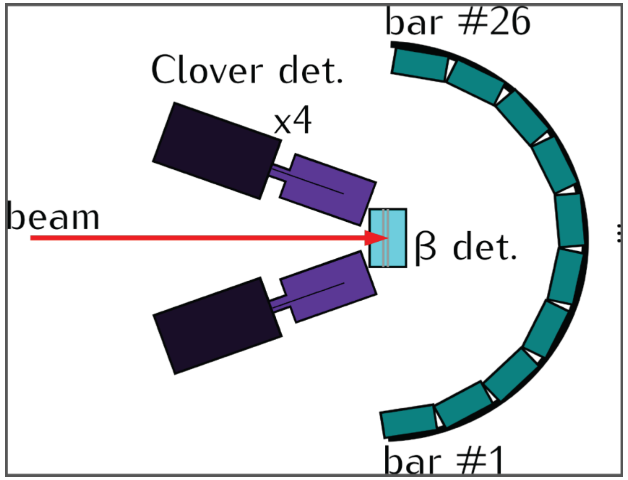
(2021) New cubic chamber employed with SiPIN and Solar Cells (York)



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

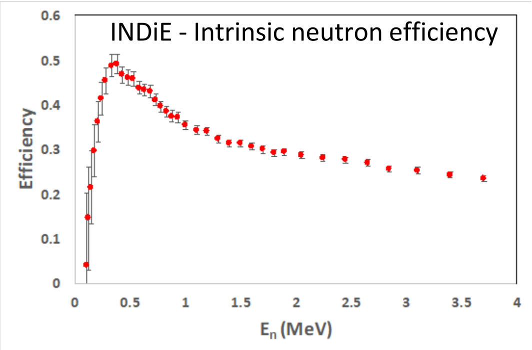
3. Neutron Spectroscopy at IDS



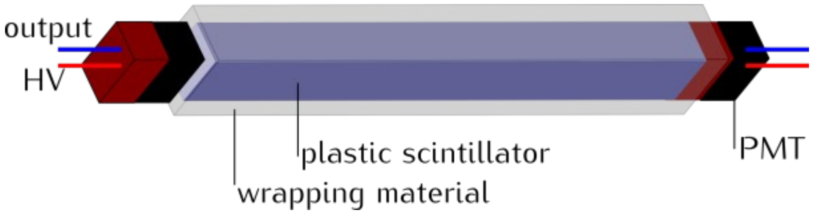


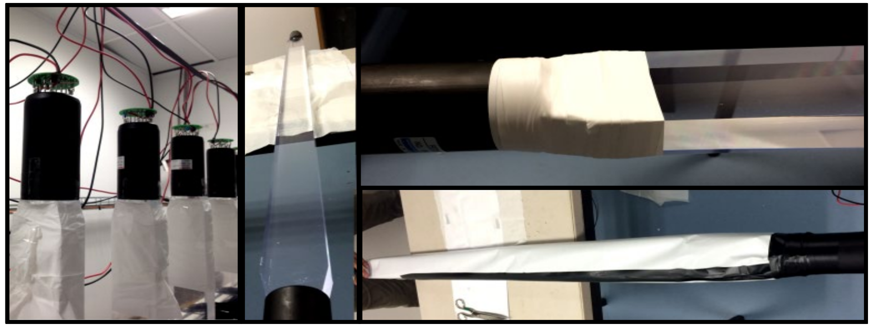
INDiE (IDS Neutron Detector)

- 26 x 3x6x120 cm^3 bars
- Ω=14.9% of 4π
- Intrinsic neutron efficiency 25%-50%
- ϵ(neutron) = 3.7%-7.5%

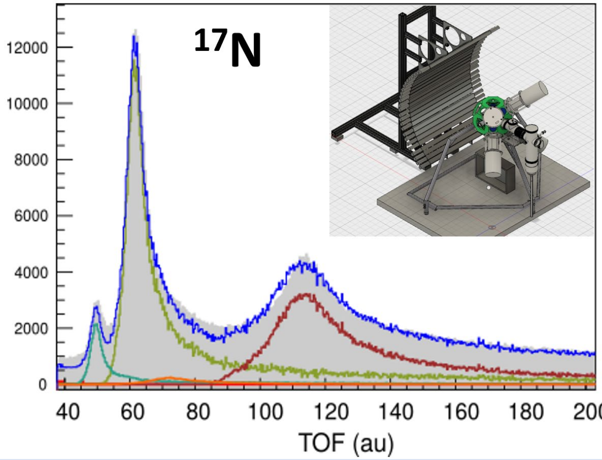


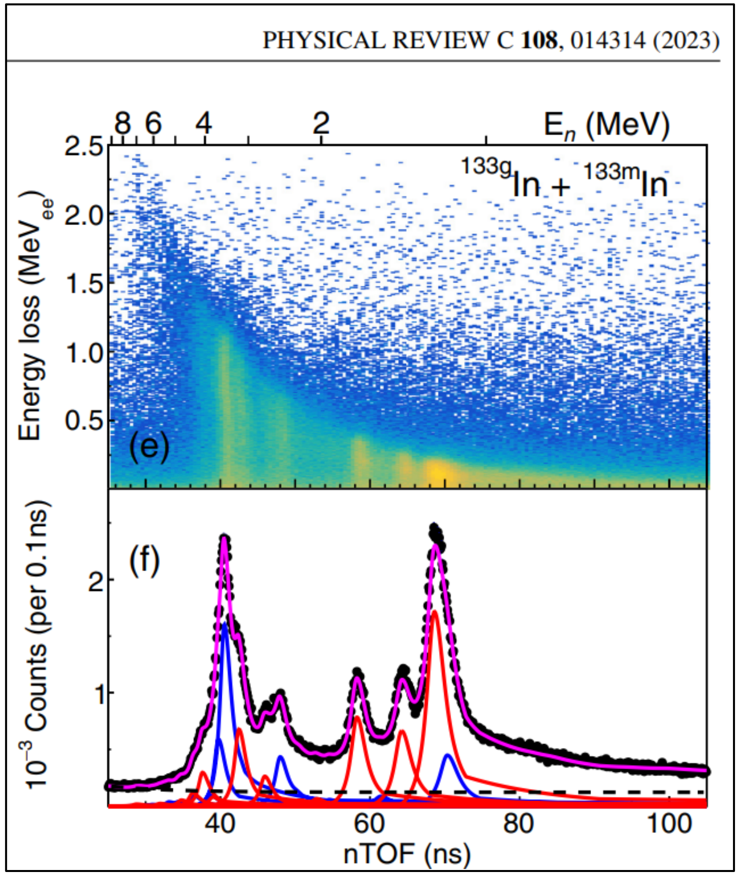
- TOF detector, inspired from the VANDLE medium bar design (UTK, USA)
- INDiE build in 2016 by the IDS local group



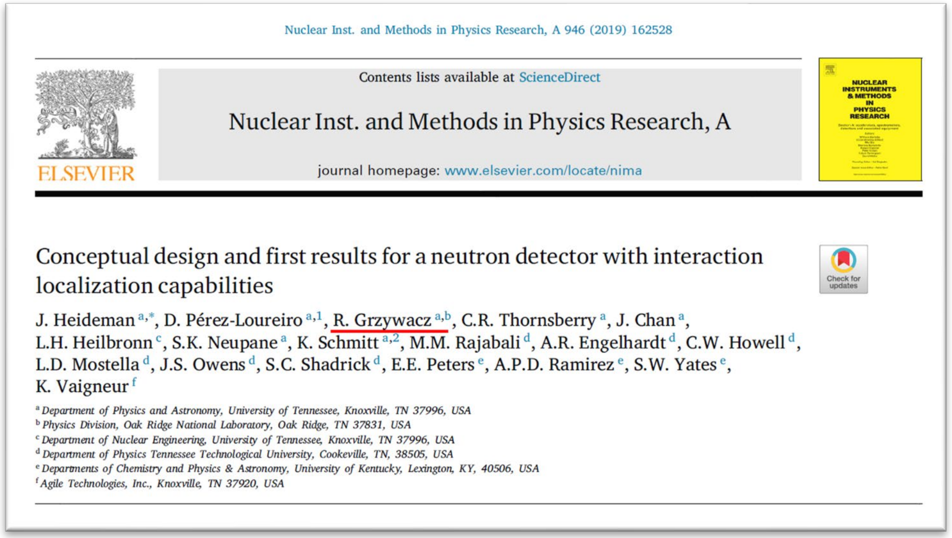


- Calibrations: ^{17}N isotopes from CaO target
- Instrument response simulation (Geant4)
  - Scattering in steel frame/floor
  - Resonance widths from literature





Future neutron spectroscopy at IDS



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

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

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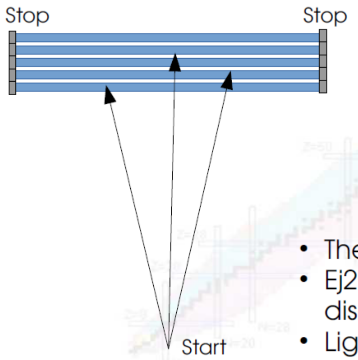
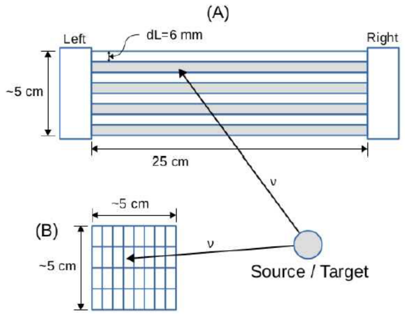
NEXT concept: tiled thin scintillator with the side light readout.

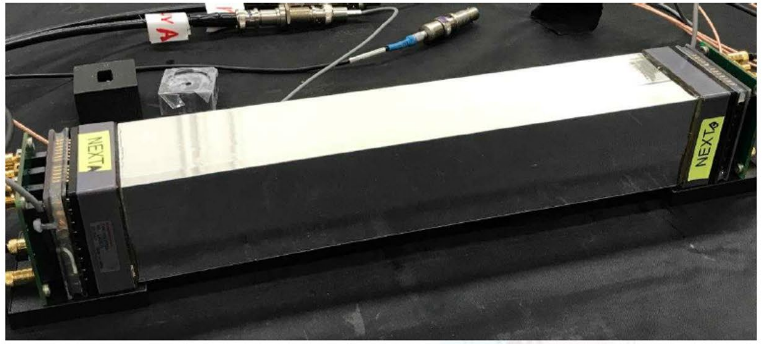
Neutron time-of-flight detector with good timing (~0.5 ns) and neutron/gamma discrimination capabilities for decay and reactions studies.
should measure 100 keV to 10 MeV neutrons





- 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.

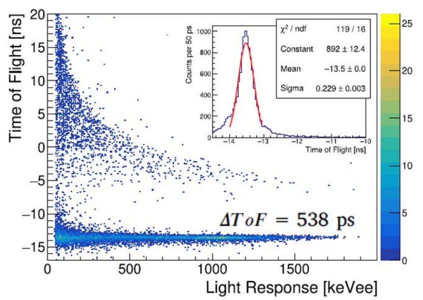
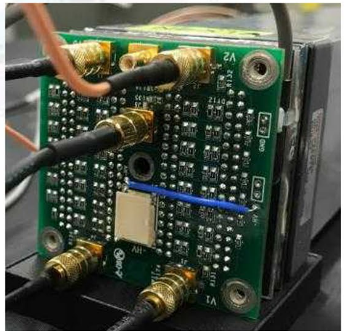
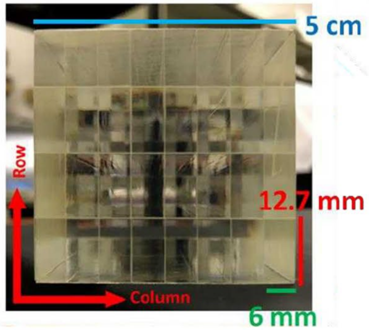
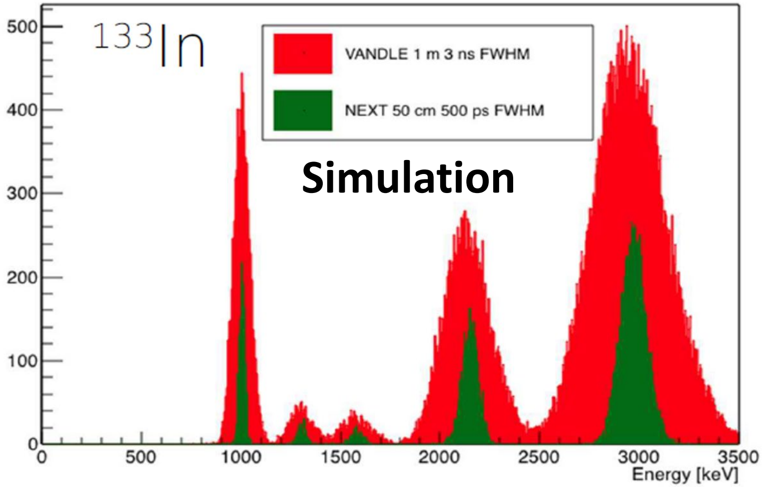


Fig. 14. Two-dimensional histogram of ^{252}Cf neutron ToF versus light response in the ESR-covered EJ-276 stop detector. The inset is a projection of the gamma-ray peak in the ToF spectrum and has ΔToF=538 ps (50 keVee threshold). The ToF data are shown here with no offset to account for inherent timestamp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





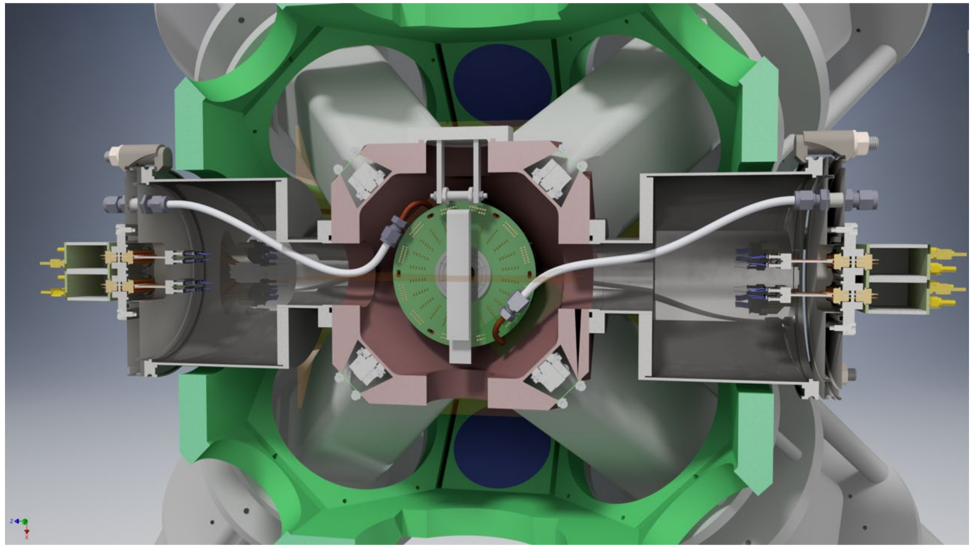


$$\left(\frac{\Delta T}{T}\right) \sim \left(\frac{2\Delta L}{L}\right)$$

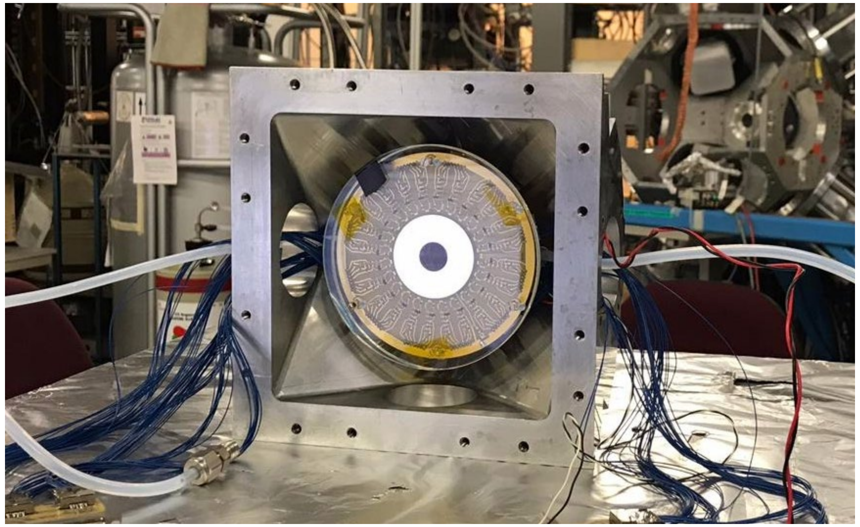
Design parameters (cost and technical feasibility)
- reduce TOF length (L)
- optimal segmentation
- best timing resolution
- electronic readout

Courtesy of R. Grzywacz

4. Conversion Electron Spectroscopy

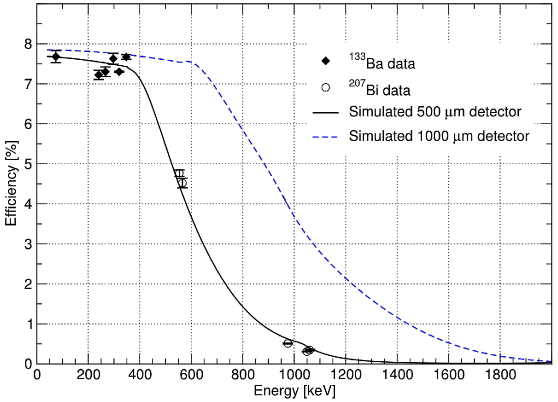


- Had to adapt current IDS setup to accommodate SPEDE detector, electronics and cooling system designed initially for MINIBALL.

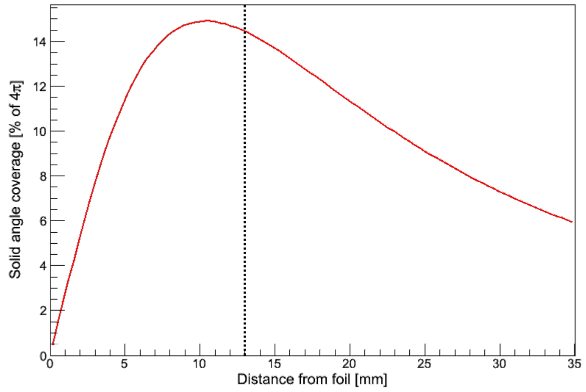


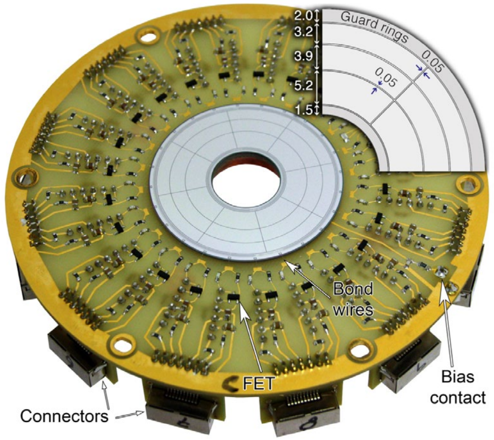
- Annular Si detector with 24 segments.
- Ethanol cooled to -20°C
- FWHM at 320 keV in the region of 6-8 keV.

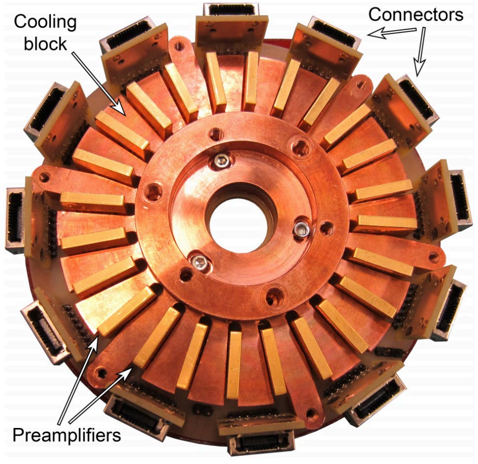
P. Papadakis et al., Eur. Phys. J. A. 54:42, 2018



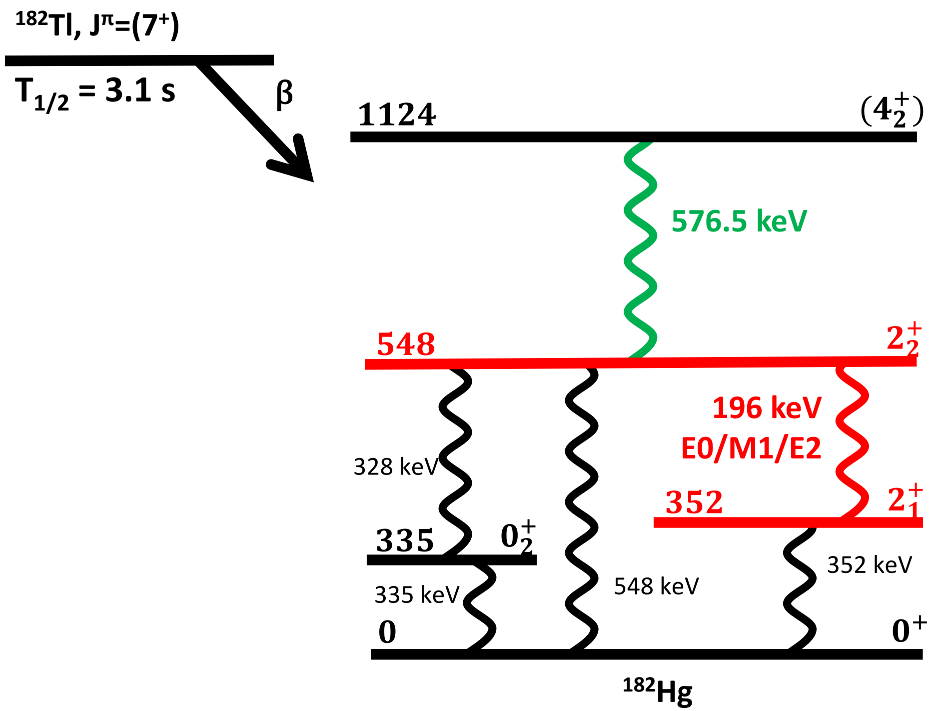
Solid angle coverage of SPEDE

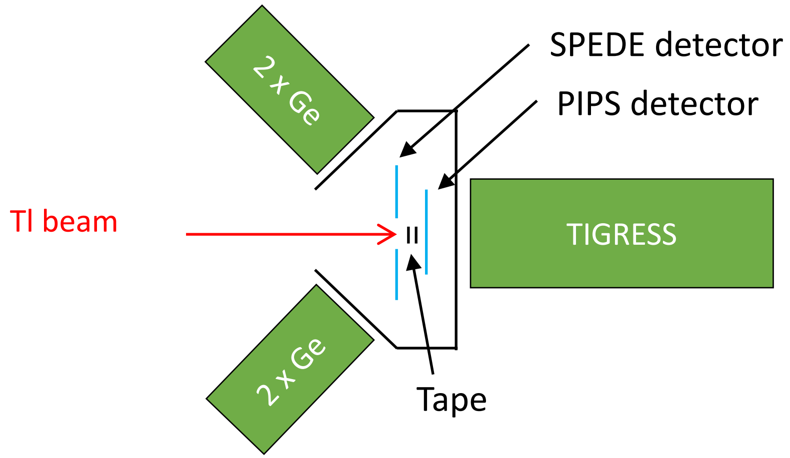


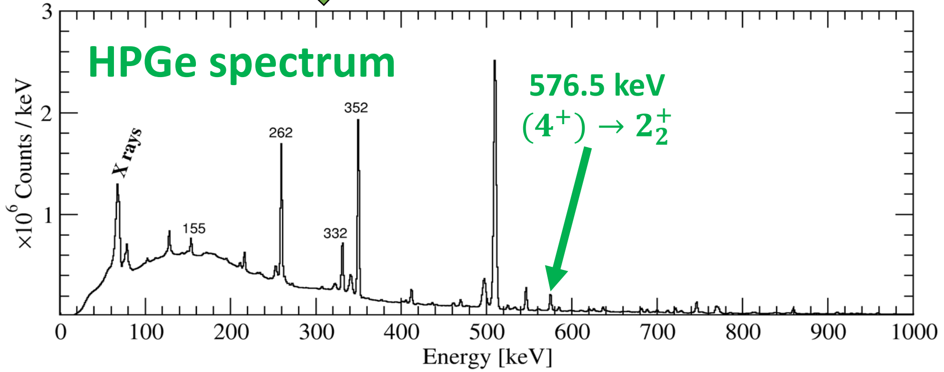


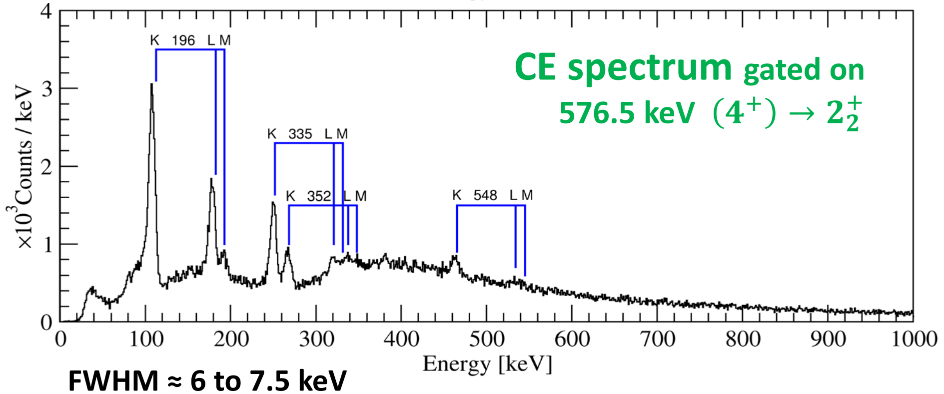


IS641 – Conversion electron spec. of ^{182,184,186}Hg isotopes









FWHM ≈ 6 to 7.5 keV

PHYSICAL REVIEW C **108**, 014308 (2023)

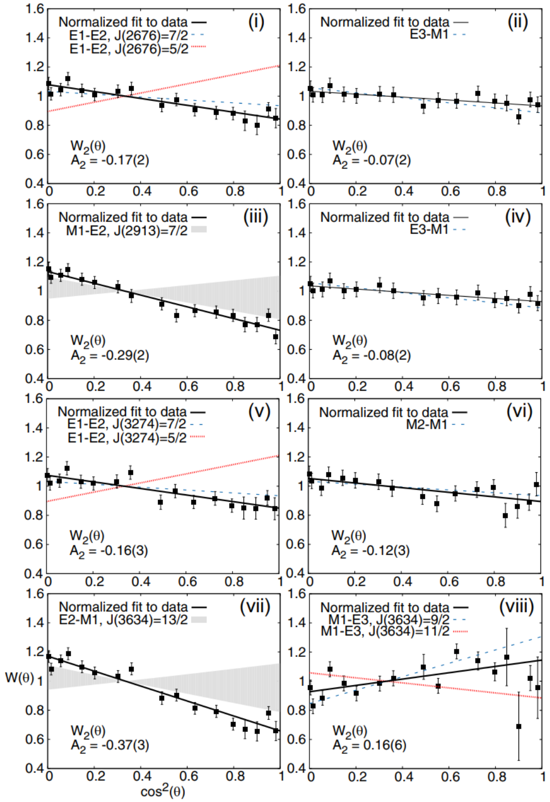
Simultaneous γ-ray and electron spectroscopy of ^{182,184,186}Hg isotopes

M. Stryjczyk,[1,2,*] B. Andel,[1,3,†] J. G. Cubiss,[4,5,†] K. Rezynkina,[1,6,†] T. R. Rodríguez,[7,8] J. E. García-Ramos,[9,10] A. N. Andreyev,[5,11] J. Pakarinen,[2,12] P. Van Duppen,[1] S. Antalic,[3] T. Berry,[13] M. J. G. Borge,[14,4] C. Clisu,[15] D. M. Cox,[16] H. De Witte,[1] L. M. Fraile,[8] H. O. U. Fynbo,[17] L. P. Gaffney,[4,18] L. J. Harkness-Brennan,[18] M. Huyse,[1] A. Illana,[19,2,8] D. S. Judson,[18] J. Konki,[4] J. Kurcewicz,[4] I. Lazarus,[20] R. Lica,[15,4] M. Madurga,[4,21] N. Marginean,[15] R. Marginean,[15] C. Mihai,[15] P. Mosat,[3] E. Nacher,[22] A. Negret,[15] J. Ojala,[2,12] J. D. Ovejas,[14] R. D. Page,[18] P. Papadakis,[18,20] S. Pascu,[15] A. Perea,[14] Zs. Podolyák,[13] L. Próchniak,[23] V. Pucknell,[20] E. Rapisarda,[4] F. Rotaru,[15] C. Sotty,[15] O. Tengblad,[14] V. Vedia,[8] S. Viñals,[14] R. Wadsworth,[5] N. Warr,[24] and K. Wrzosek-Lipska[23]
(IDS Collaboration)

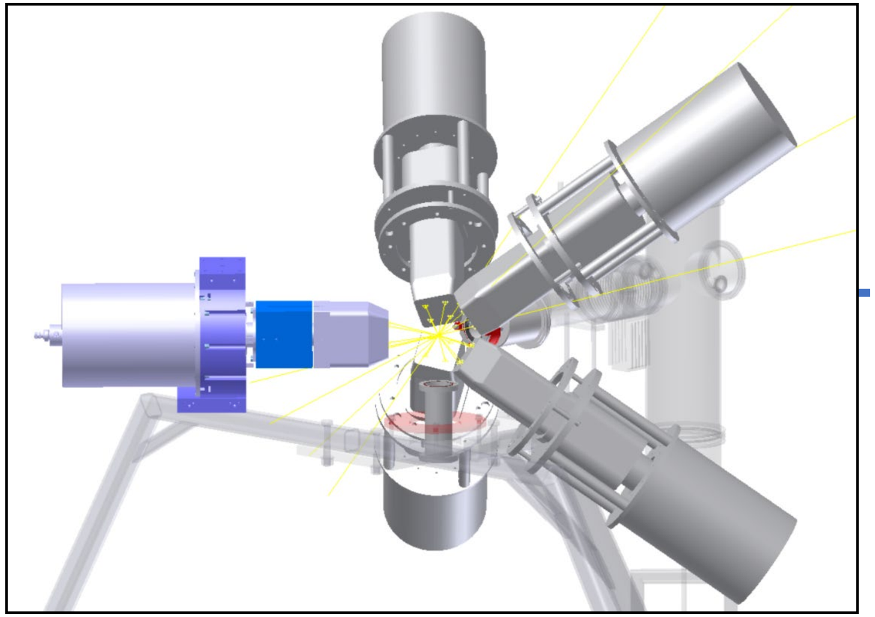
5. High beta-gamma efficiency

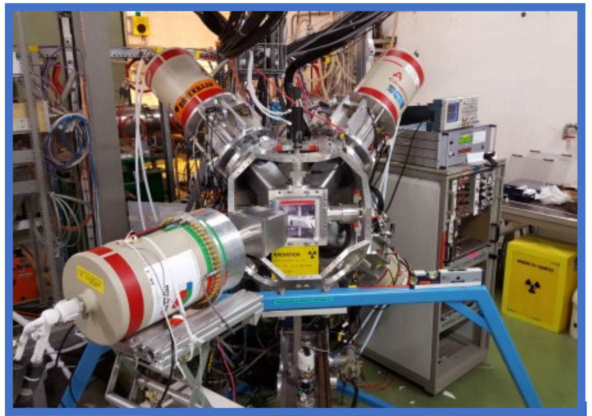
Detection setup

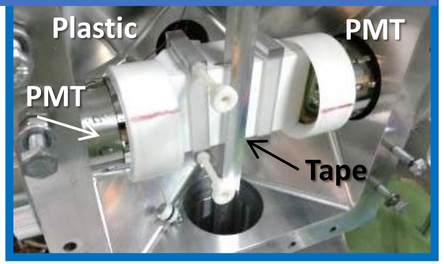
- 5 Clover detectors
- ~4π plastic scintillator around the implantation point
- 5th Clover can be placed at a specific angle to perform **angular correlation studies [1]**.



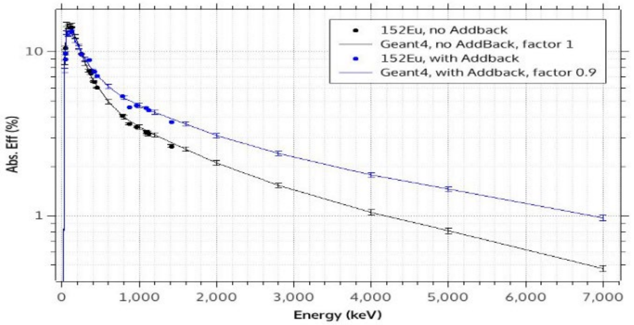
[1] T. A. Berry et al., Phys. Rev. C101, 054311 (2020)

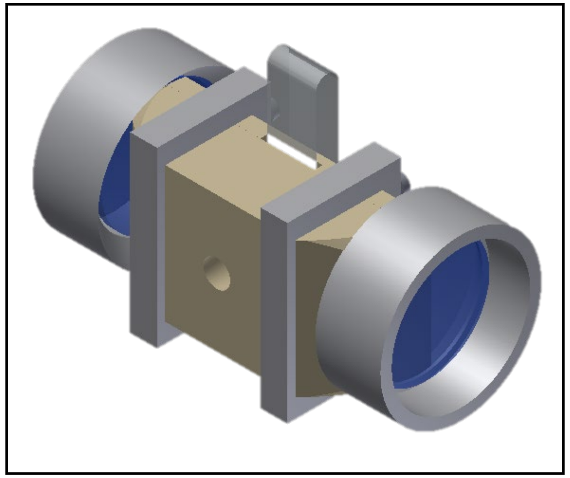




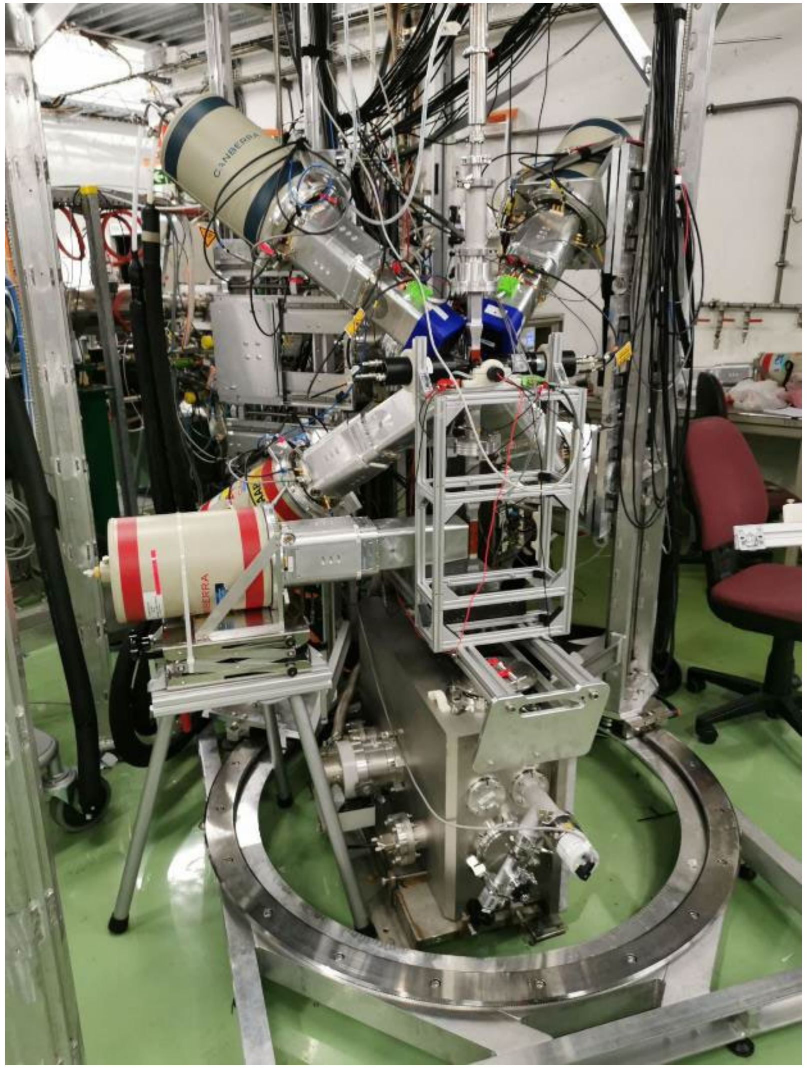


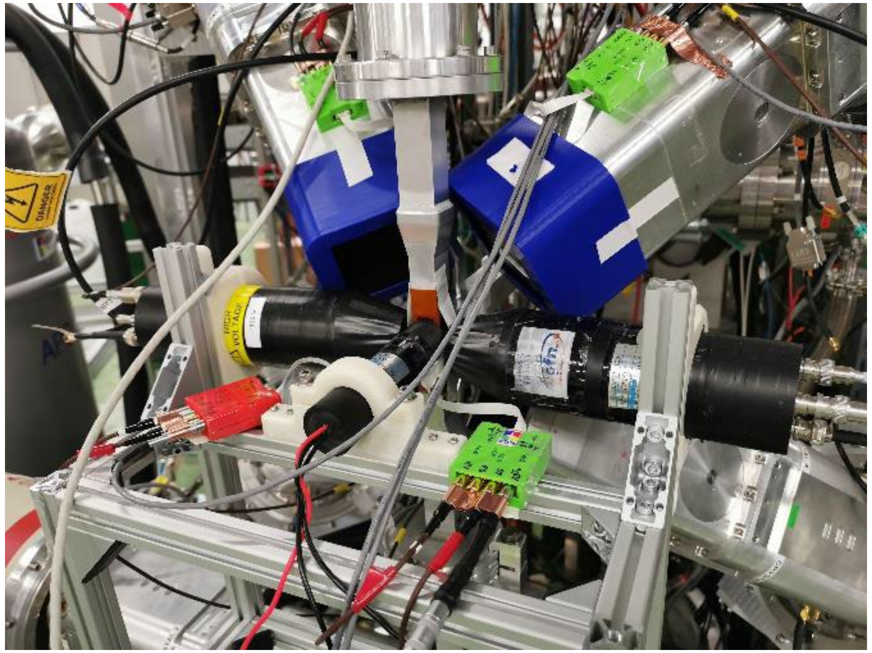
- **Absolute β efficiency - 90(5) %**
  (single/beta gated ratios)
- **Absolute γ efficiency - 4% @1MeV**
  Using GEANT4 to extrapolate

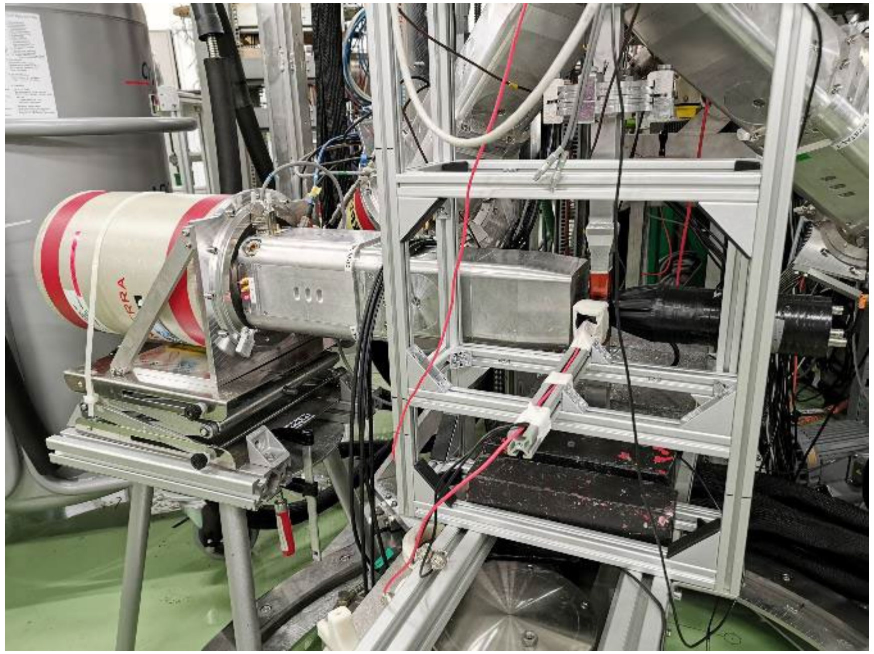




New structure – 2023 campaign

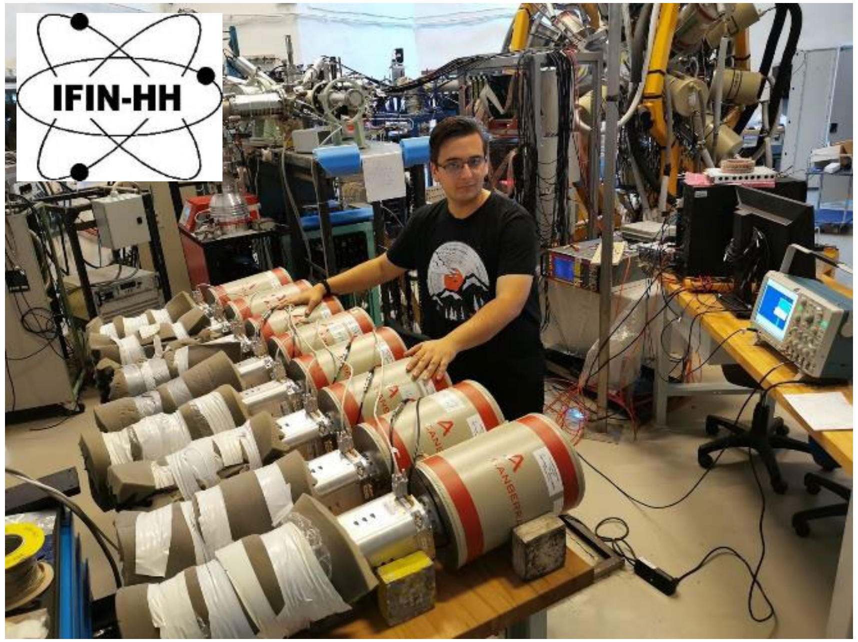




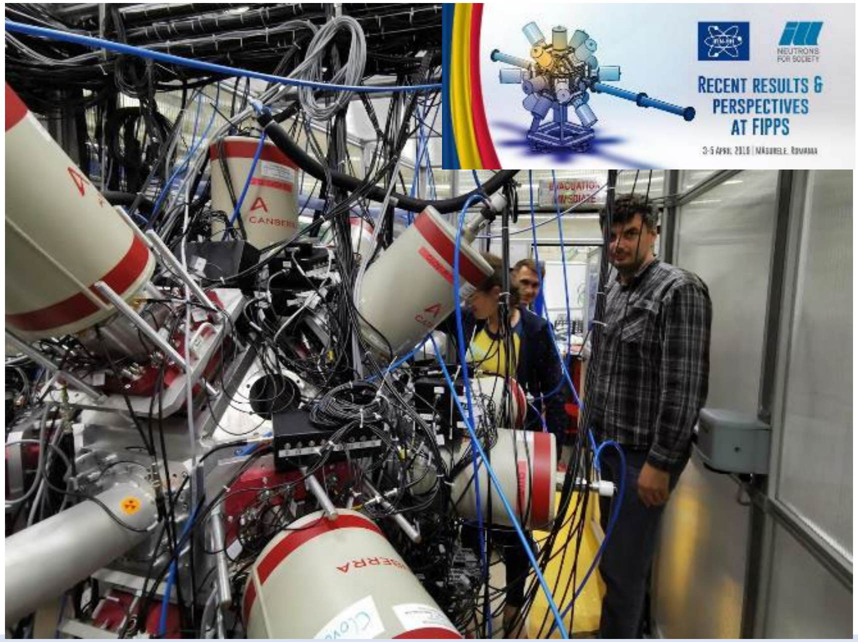


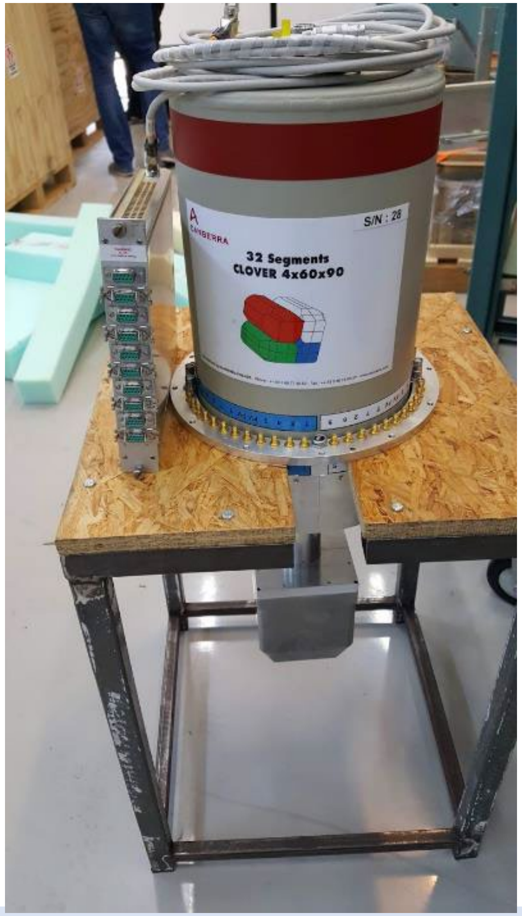
>15 Available HPGE detectors

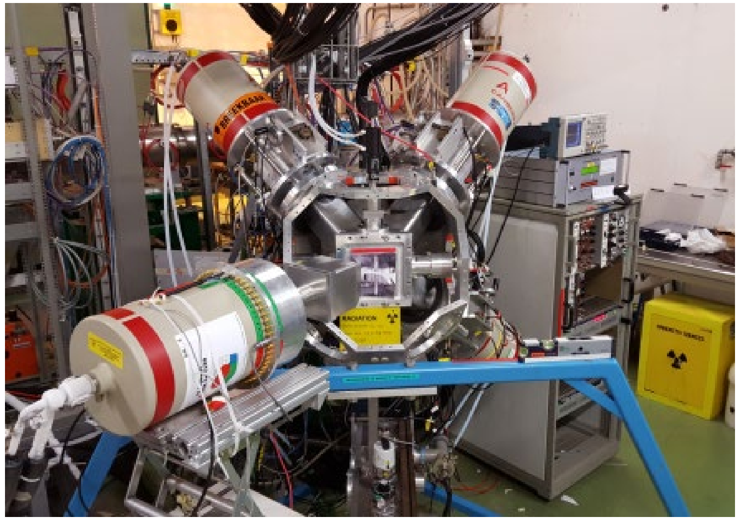
Permanent at IDS: 6 HPGe Clover detectors
2 standard window (IFIN-HH), 4 thin window (KUL)



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







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

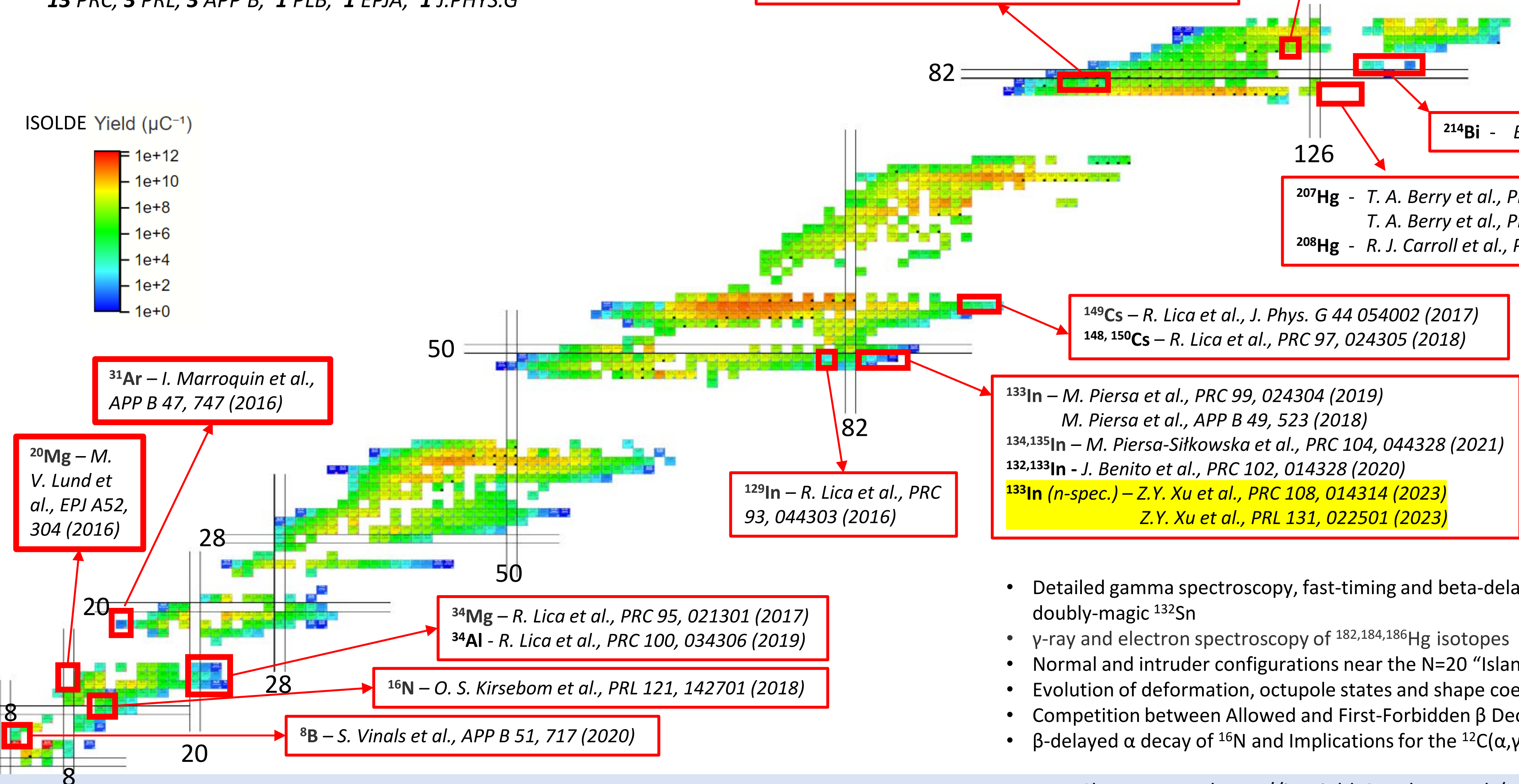
+ Others (coaxial, x-ray, etc.)

Beta-decay studies published from IDS

(experiments performed between 2014-2018)

Publications: **22**

13 *PRC,* ***3*** *PRL,* ***3*** *APP B,* ***1*** *PLB,* ***1*** *EPJA,* ***1*** *J.PHYS.G*



^{208}At - *M. Brunet et al., PRC 103, 054327 (2021)*

^{186}Tl - *M. Stryjczyk et al., PRC 102, 024322 (2020)*
^{182,184,186}Tl - *M. Stryjczyk et al., PRC 108, 014308 (2023)*

^{214}Bi - *B. Andel et al., PRC 104, 054301 (2021)*

^{207}Hg - *T. A. Berry et al., PLB 793, 271-275 (2019);*
T. A. Berry et al., PRC 101, 054311 (2020)
^{208}Hg - *R. J. Carroll et al., PRL 125, 192501 (2020)*

^{149}Cs – *R. Lica et al., J. Phys. G 44 054002 (2017)*
^{148,150}Cs – *R. Lica et al., PRC 97, 024305 (2018)*

^{133}In – *M. Piersa et al., PRC 99, 024304 (2019)*
M. Piersa et al., APP B 49, 523 (2018)
^{134,135}In – *M. Piersa-Siłkowska et al., PRC 104, 044328 (2021)*
^{132,133}In - *J. Benito et al., PRC 102, 014328 (2020)*
^{133}In *(n-spec.) – Z.Y. Xu et al., PRC 108, 014314 (2023)*
Z.Y. Xu et al., PRL 131, 022501 (2023)

^{129}In – *R. Lica et al., PRC 93, 044303 (2016)*

^{31}Ar – *I. Marroquin et al., APP B 47, 747 (2016)*

^{20}Mg – *M. V. Lund et al., EPJ A52, 304 (2016)*

^{34}Mg – *R. Lica et al., PRC 95, 021301 (2017)*
^{34}Al - *R. Lica et al., PRC 100, 034306 (2019)*

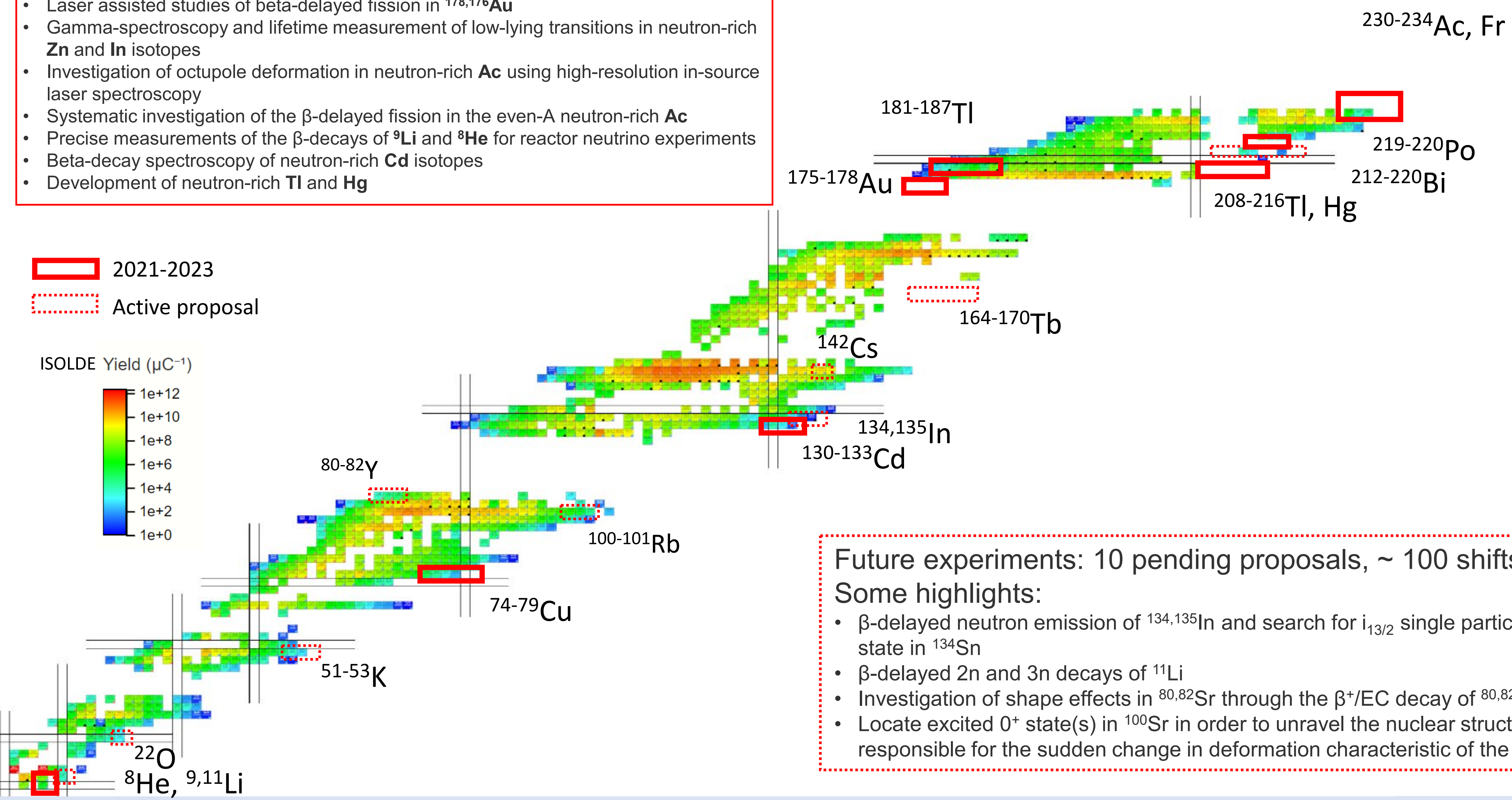
^{16}N – *O. S. Kirsebom et al., PRL 121, 142701 (2018)*

^{8}B – *S. Vinals et al., APP B 51, 717 (2020)*

- Detailed gamma spectroscopy, fast-timing and beta-delayed neutron spectroscopy in the doubly-magic ^{132}Sn
- γ-ray and electron spectroscopy of ^{182,184,186}Hg isotopes
- Normal and intruder configurations near the N=20 "Island of Inversion" (^{34}Si)
- 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)
- β-delayed α decay of ^{16}N and Implications for the ^{12}C(α,γ)^{16}O Astrophysical Reaction Rate

Recent and future experiments at IDS

- Laser assisted studies of beta-delayed fission in ^{178,176}**Au**
- Gamma-spectroscopy and lifetime measurement of low-lying transitions in neutron-rich **Zn** and **In** isotopes
- Investigation of octupole deformation in neutron-rich **Ac** using high-resolution in-source laser spectroscopy
- Systematic investigation of the β-delayed fission in the even-A neutron-rich **Ac**
- Precise measurements of the β-decays of ^{9}**Li** and ^{8}**He** for reactor neutrino experiments
- Beta-decay spectroscopy of neutron-rich **Cd** isotopes
- Development of neutron-rich **Tl** and **Hg**



>2023

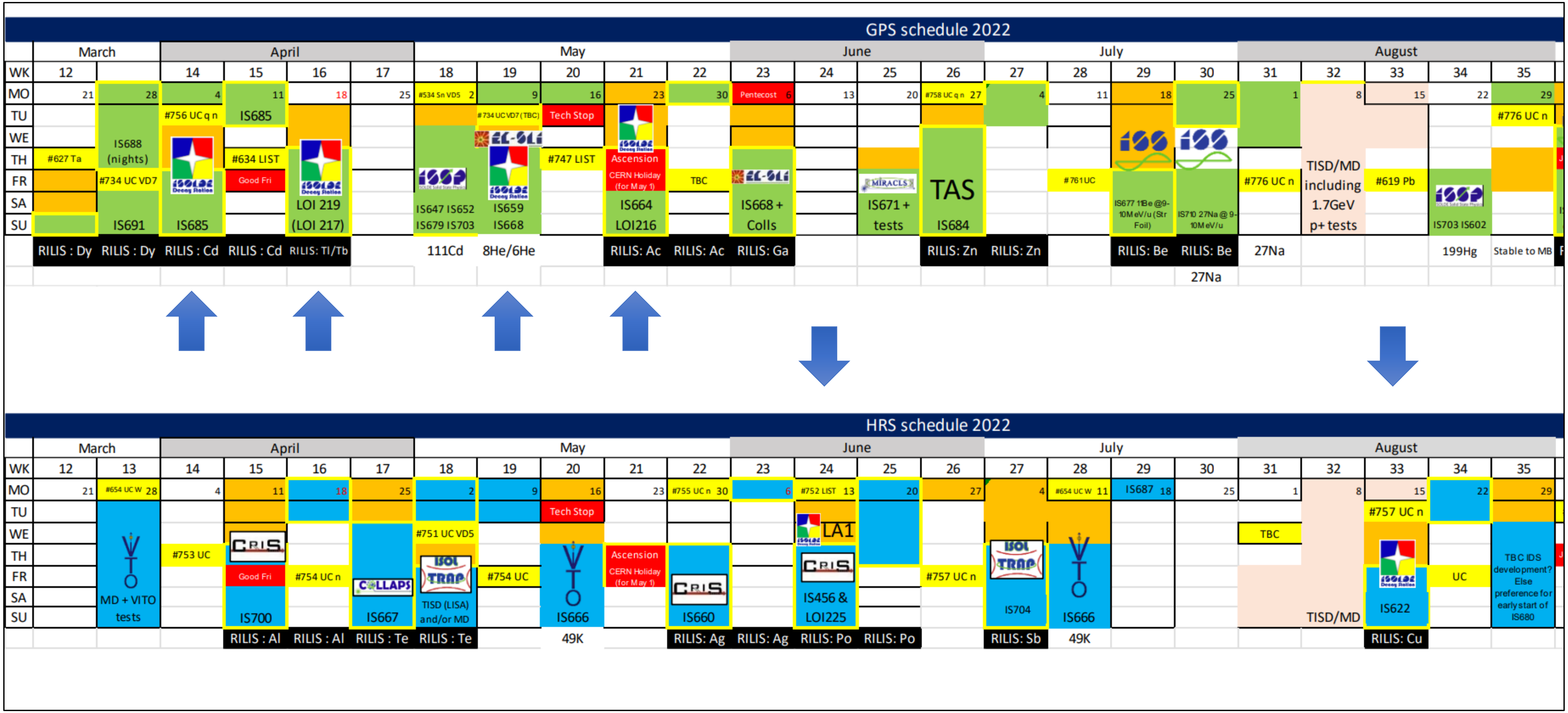
Future experiments: 10 pending proposals, ~ 100 shifts
Some highlights:

- 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 ^{11}Li
- 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

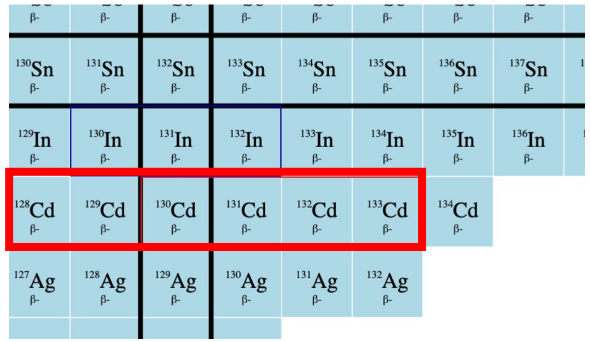
Chart source: https://isoyields2.web.cern.ch/IsoldeYieldChart.aspx

ISOLDE Schedule March – August 2022

(busiest experimental campaign for IDS so far!)

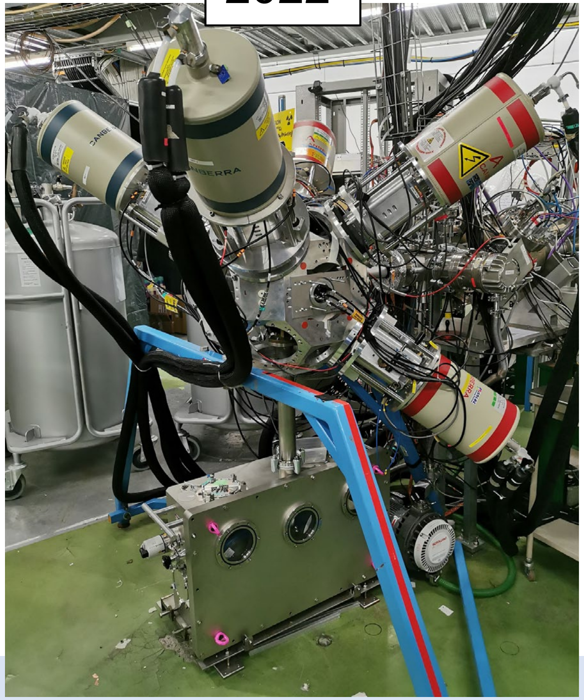


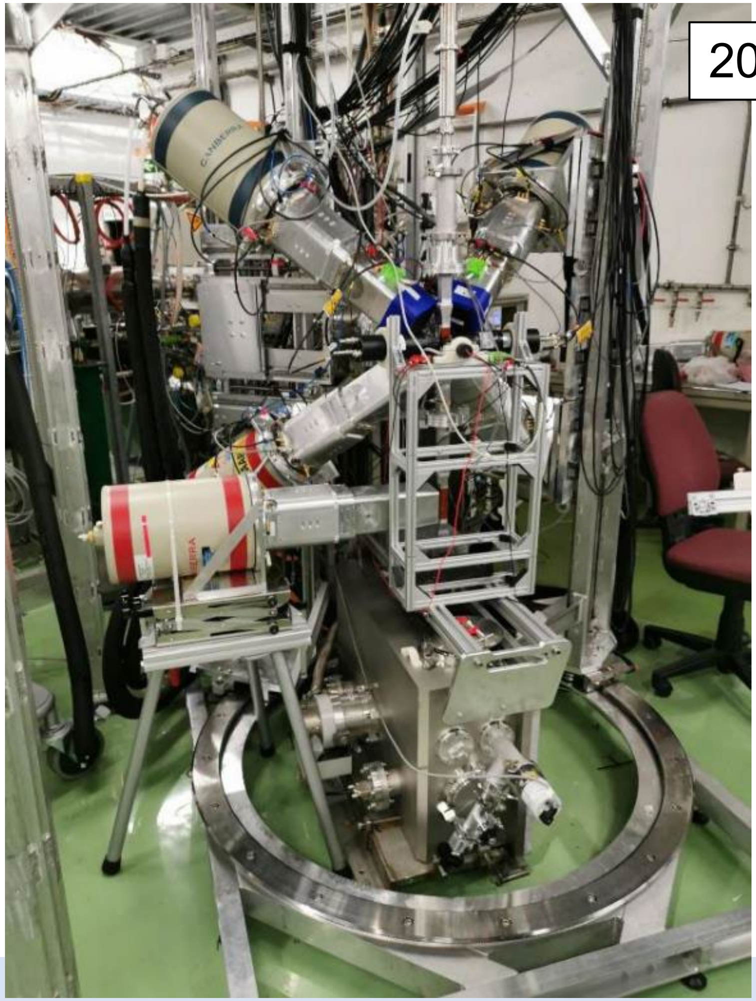
IS685: Beta-decay spectroscopy of neutron-rich **Cd** isotopes (L.M. Fraile, A. Korgul)



- Investigate the β decay of $^{130\text{-}133}$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

2022



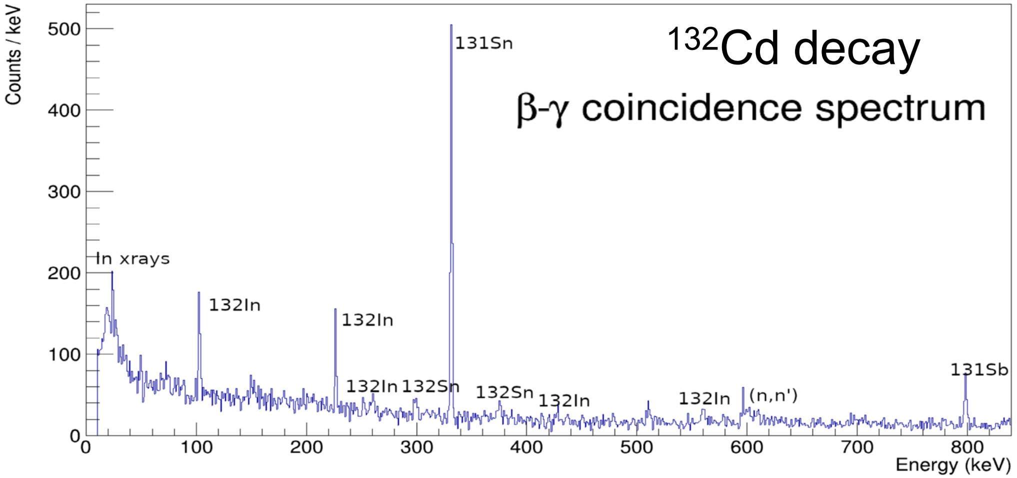


2023

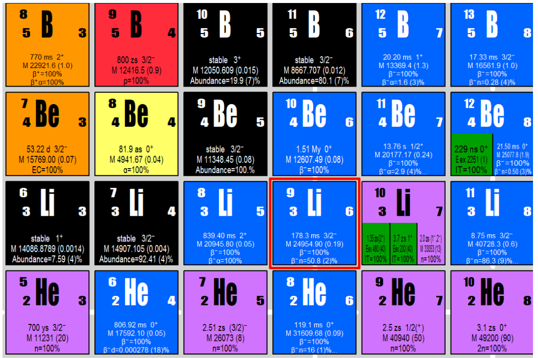
Good production in 2023:

^{130}Cd: ~3000 ions/uC
^{131}Cd: ~30 ions/uC;
^{132,133}Cd: few ions/uC

(UCx Target + Quartz line + Neutron Converter + RILIS)

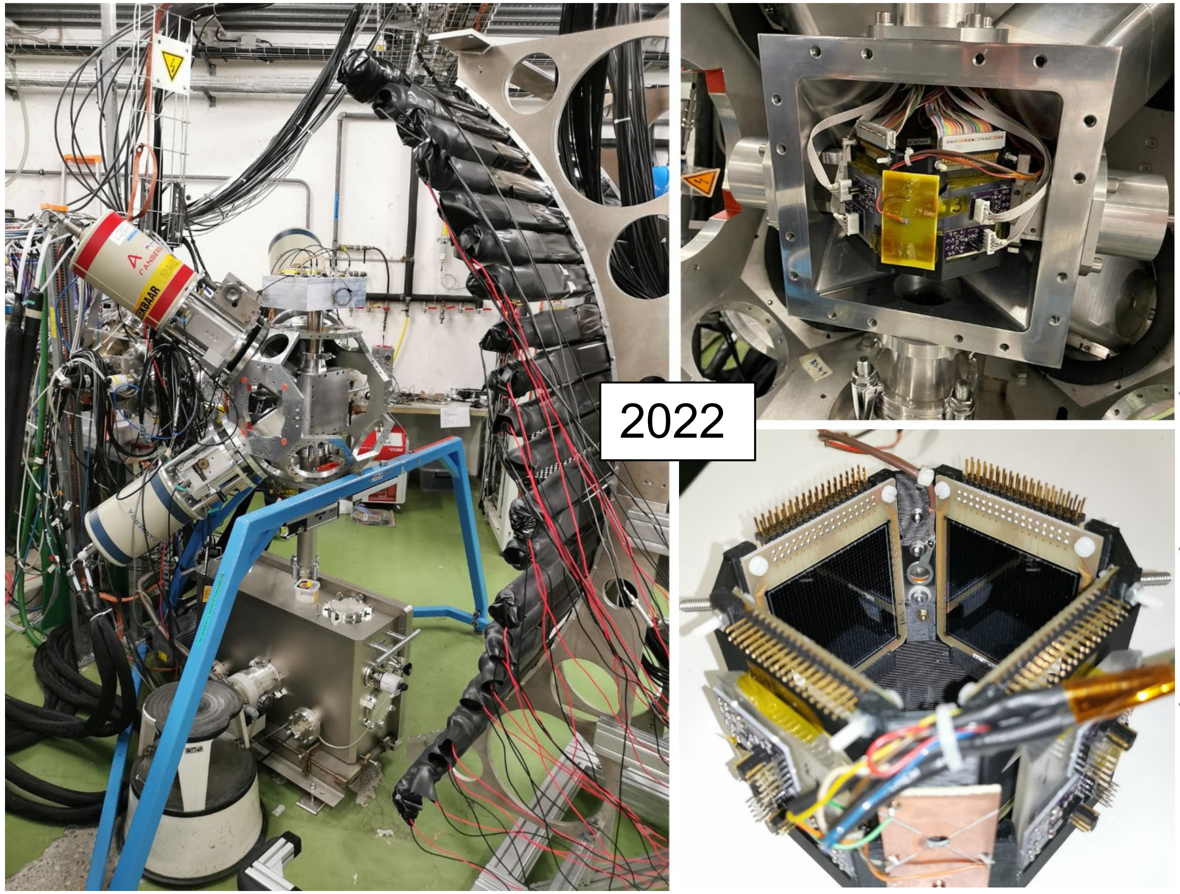


IS659: Precise measurements of the β-decays of **^{9}Li** and **^{8}He** for reactor neutrino experiments (H.O.U. Fynbo)



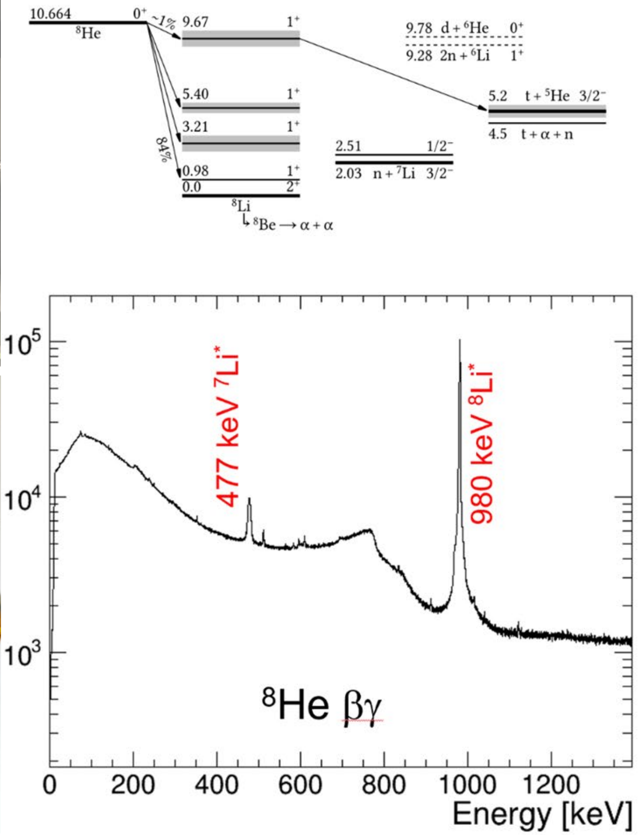
- ^{9}Li and ^{8}He -> some of largest cosmogenic background sources for reactor neutrino experiments
- Need to extract more precise energy levels and branching ratios for ^{9}Li and ^{8}He and decay products.
- 2022: intense production of ^{8}He (UC target)

New IDS configuration: Neutron+Particle spectroscopy

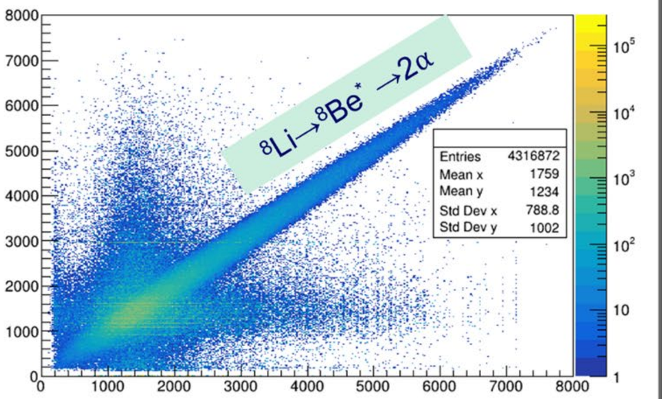


Measured spectra

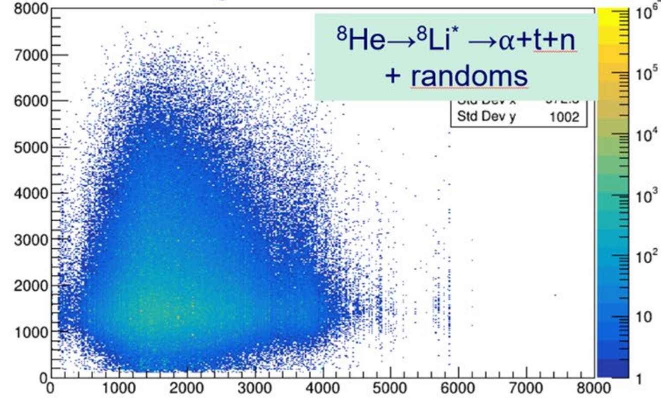
Preliminary data analysis



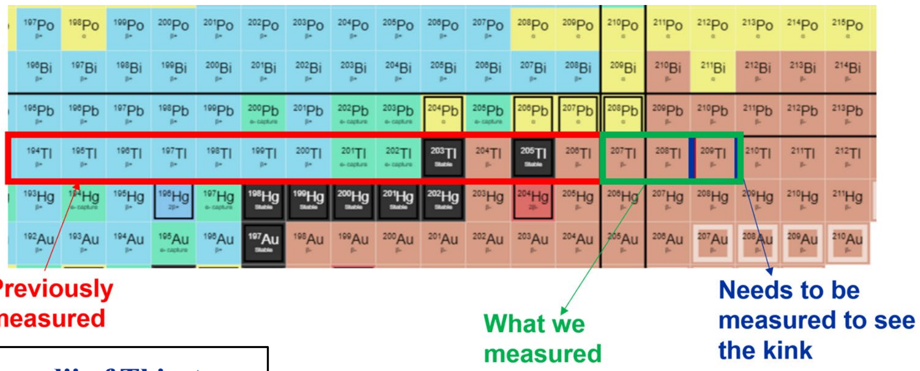
Opposing detectors



Adjacent detectors

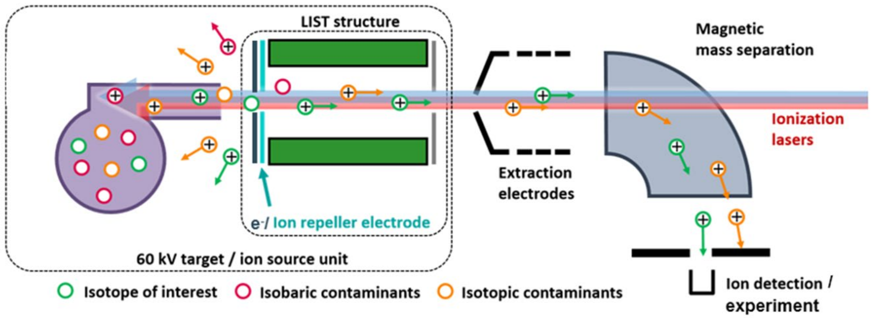


LOI219: Development of neutron-rich Tl beams for nuclear structure studies beyond ^{208}**Pb** (A. Gottardo, R. Lica, R. Heinke, A. Andreyev et al.)



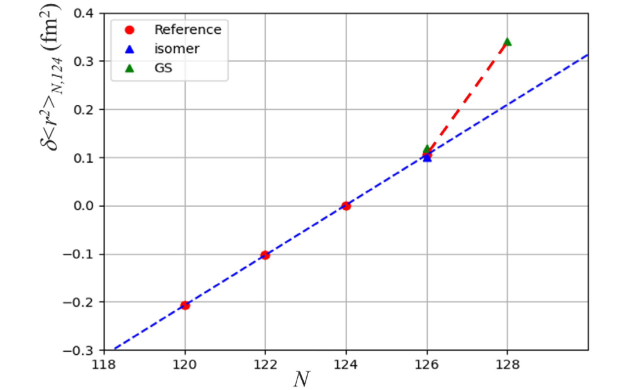
Preliminary results from laser spectroscopy of Thallium isotopes near N=126

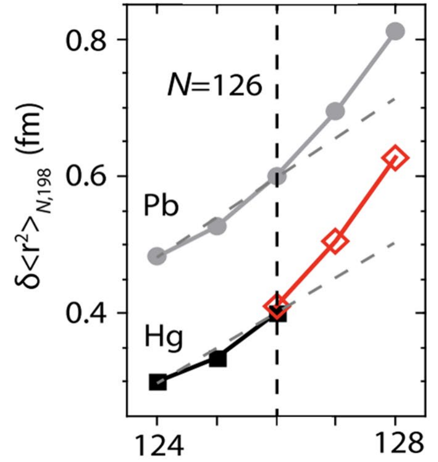
- LIST Ion source was used to overcome the isobaric Fr contamination (easily surface ionized)



Kink in mean square charge radii of Tl isotopes

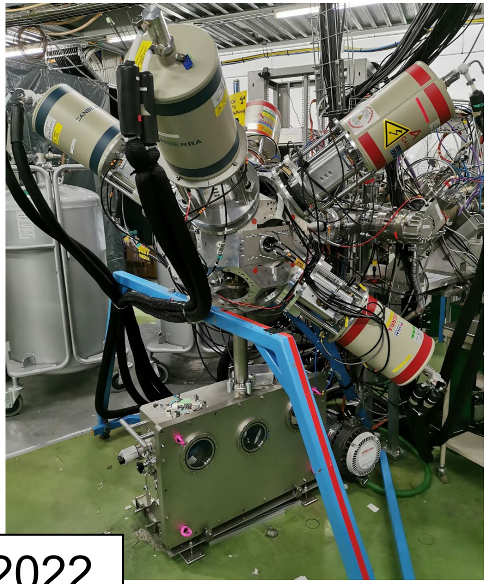
Change in mean square charge radii respective to ^{205}Tl for even-N Tl nuclei





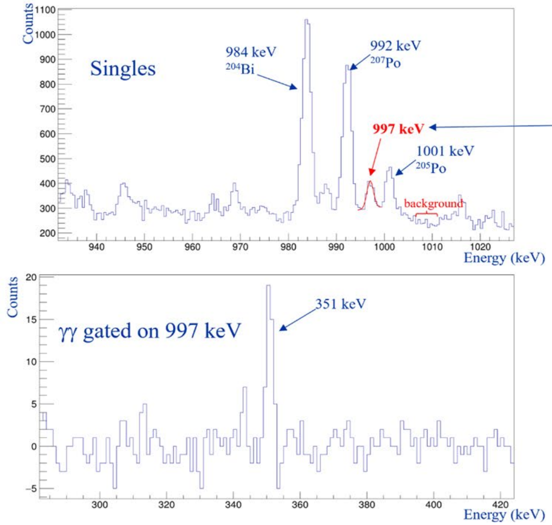
Kink in mean square charge radii of Pb and Hg across N=126[2]

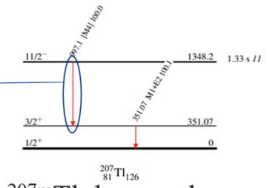
IDS Fast-timing setup



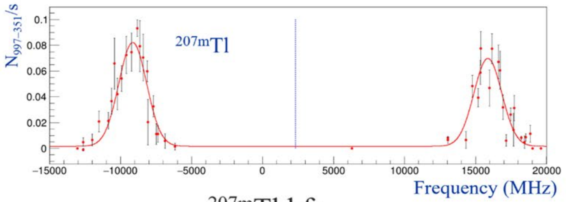
2022

207mTl hfs measurement



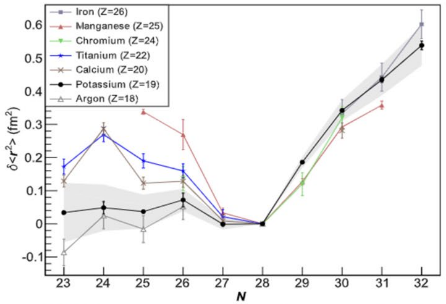


207mTl decay scheme



207mTl hfs

e

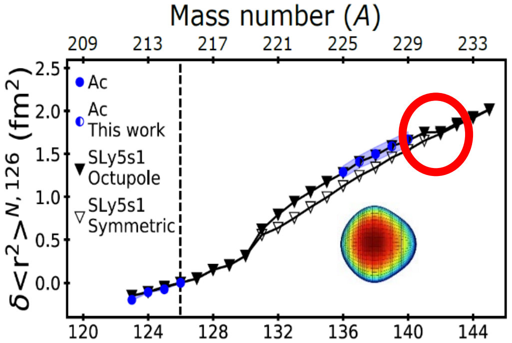


Kink in mean square charge radii of different isotopes across N=28 [1]

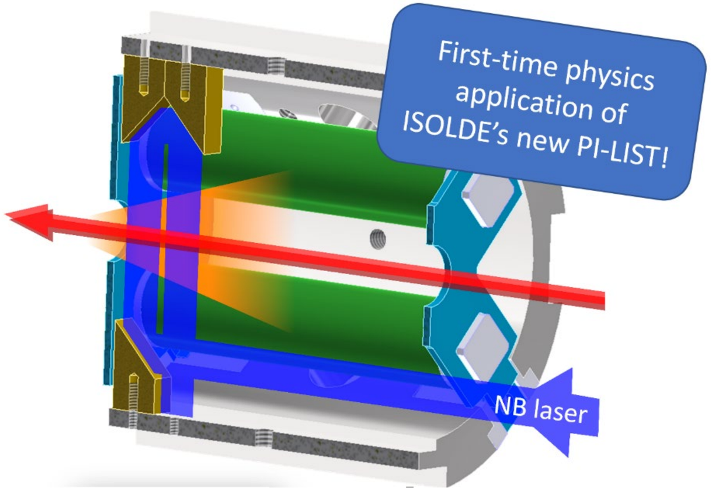
Courtesy of Z. Yue (Uni. York) – to be submitted Jul 2023

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

- $^{224-231}$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})

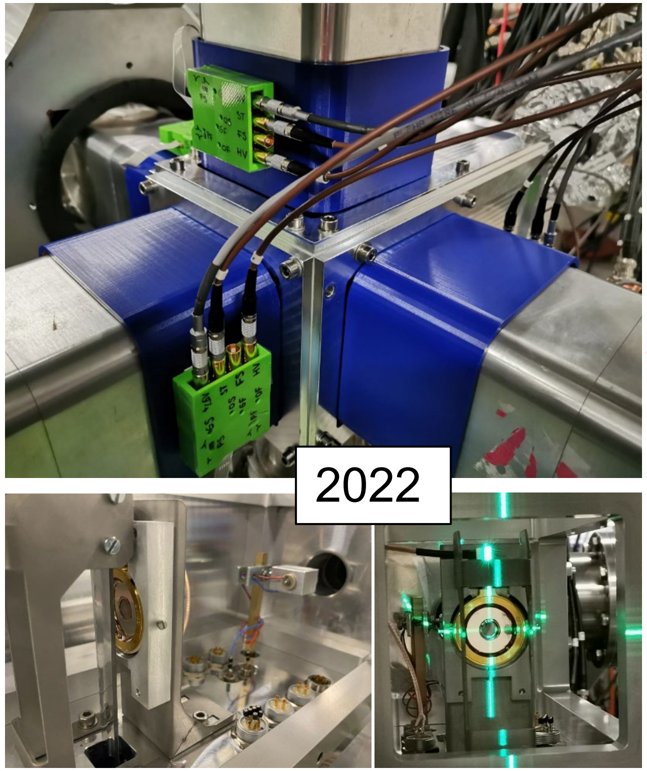


IDS
+
ASET
(LA1)
+
Ion
Counter

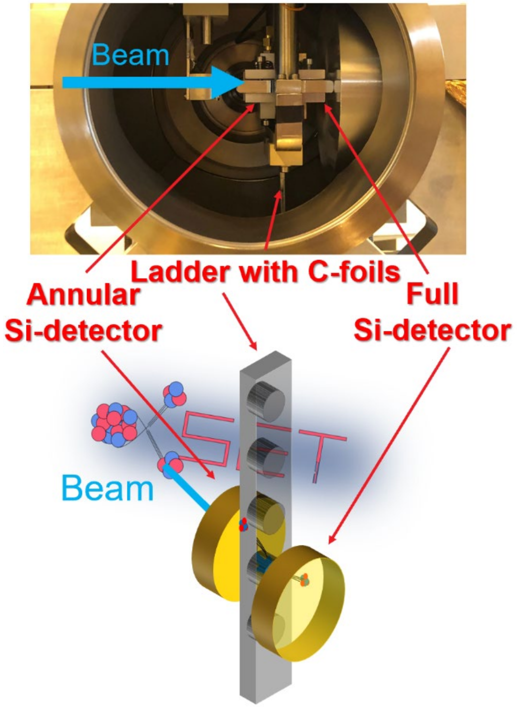


PI-LIST = Perpendicularly Illuminated Laser Ion Source and Trap

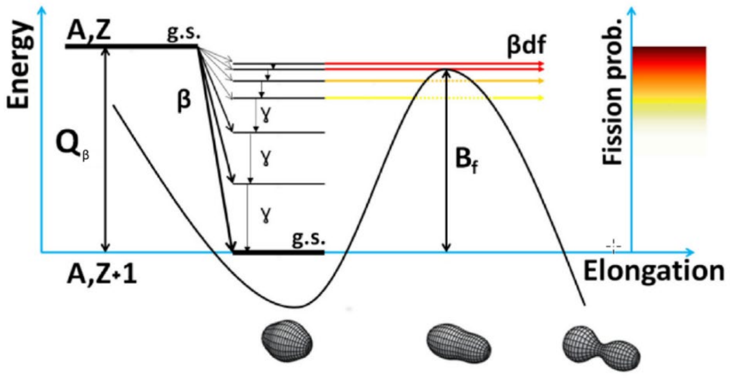
IDS Cubic Chamber + Annular Si



ASET @ LA1

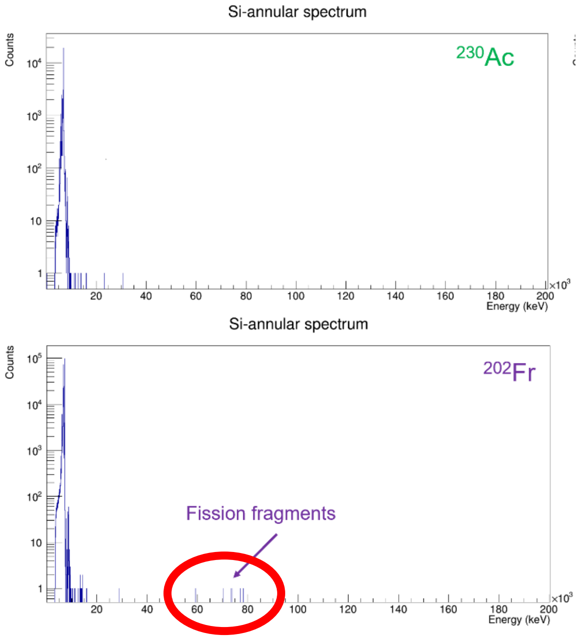


β-delayed fission (βDF) is a two-step process, where the β-decay of a nucleus is followed by the fission of the daughter



The best condition for it to happen is when

$Q_\beta - B_f \gtrsim -3$ MeV



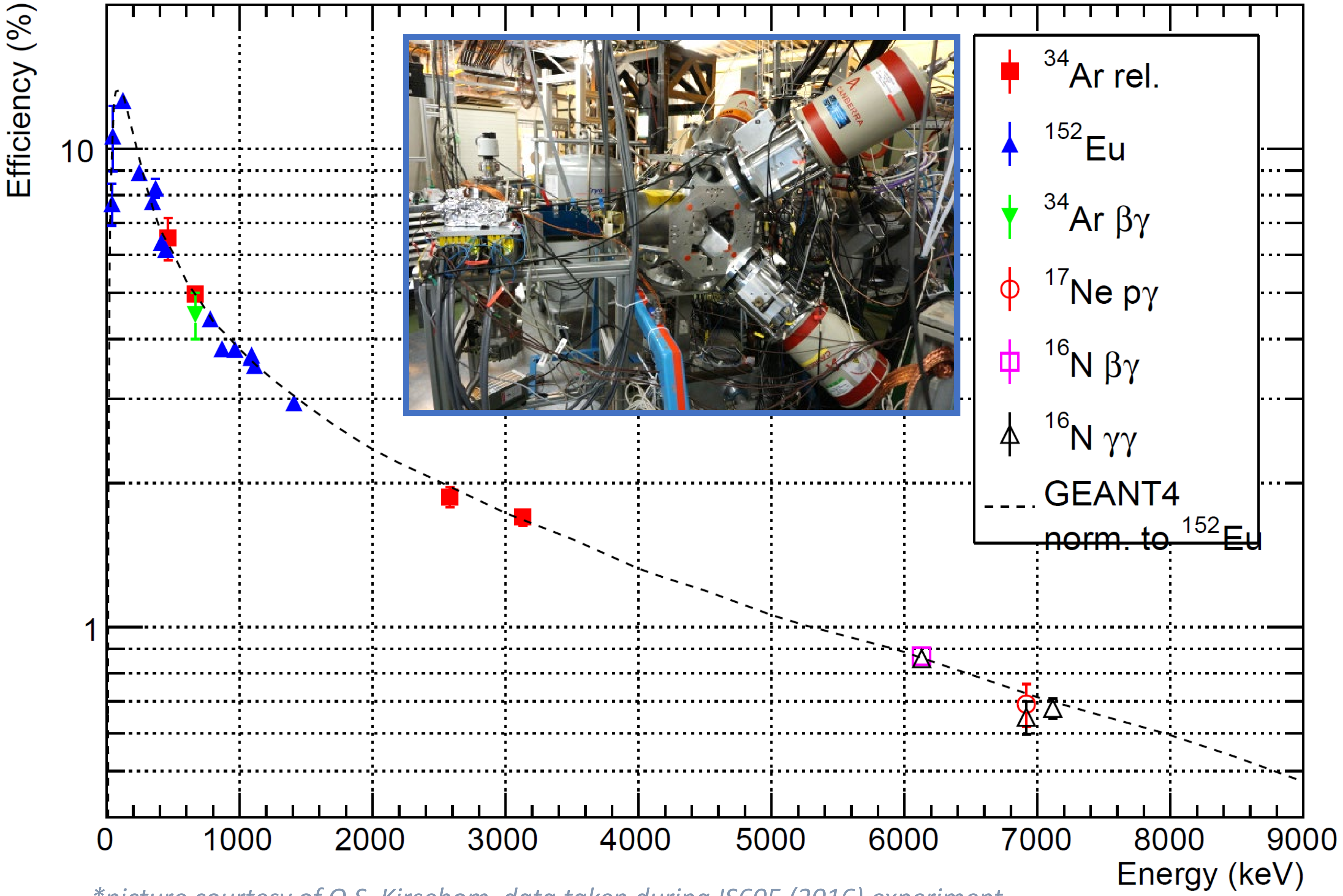
Conclusions

- **ISOLDE** is the 1st ISOL-type facility and can provide ~1000 radioactive nuclides to various experiments
- Physics interest: nuclear physics, via astrophysics and fundamental studies to applications
- A dozen fixed setups cover above topics (and many travelling experiments)

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

Thank you for your attention!

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