ISOLDE Decay Station: Year one and near future physics program

M. Madurga

A multipurpose Decay spectroscopy for ISOLDE

The **I**SOLDE **D**ecay **S**tation (**IDS**) project aimed to provide:

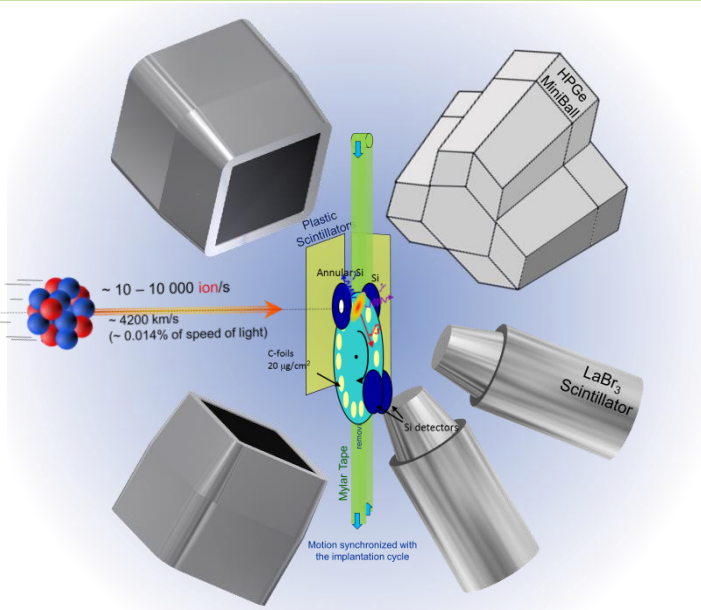
- **Permanent** Setup for decay studies using the RIB from ISOLDE
- **Flexible** (for several decay types or studies)

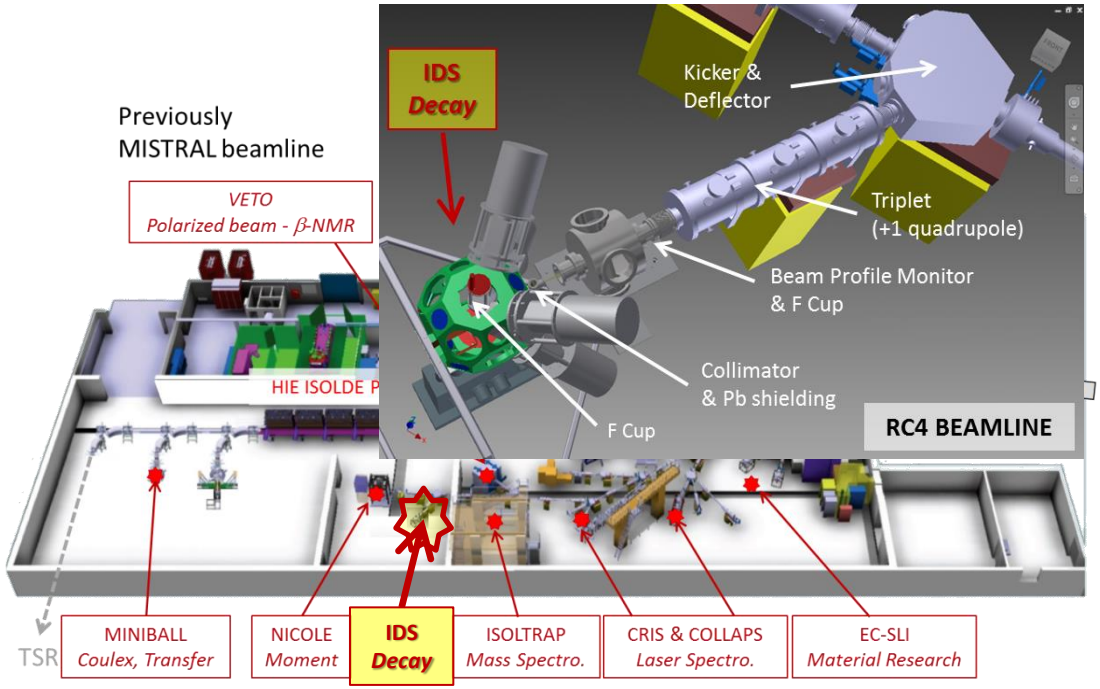
  Basic approach:

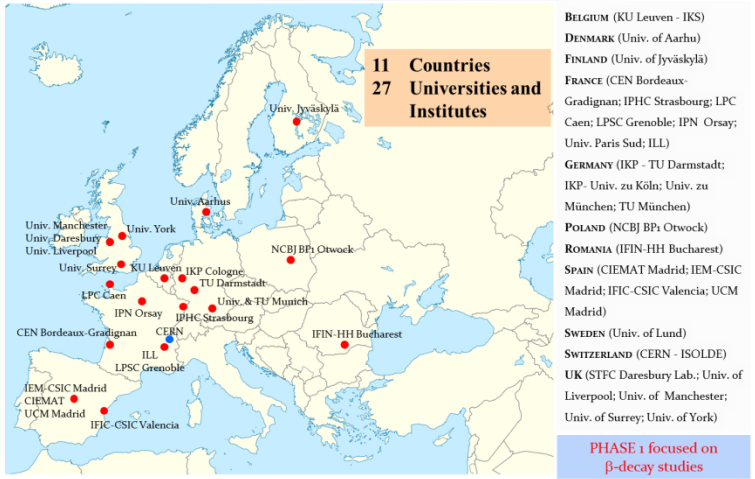
  High Pure Ge-detector (4 clovers and up to 3 MiniBall detectors)

  + Ancillary detectors ($LaBr_3$, plastic scintillator, silicon, neutron detectors, …)

  + Tape station/Windmill implantation chamber
- **Form a collaboration** to support and perform decay studies at ISOLDE

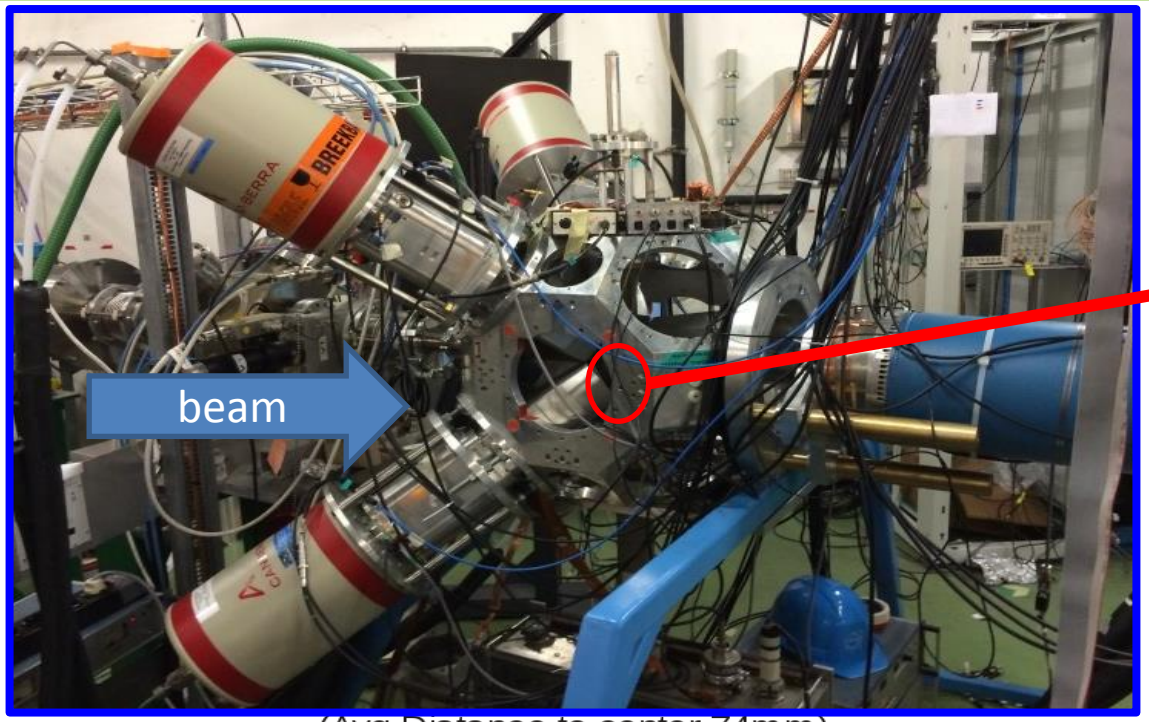


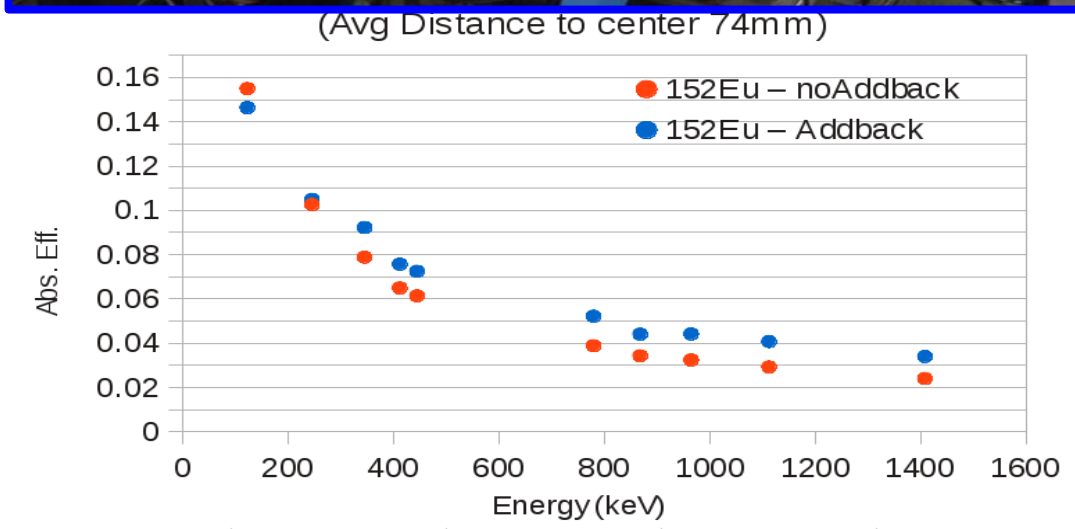




PRELIMINARY

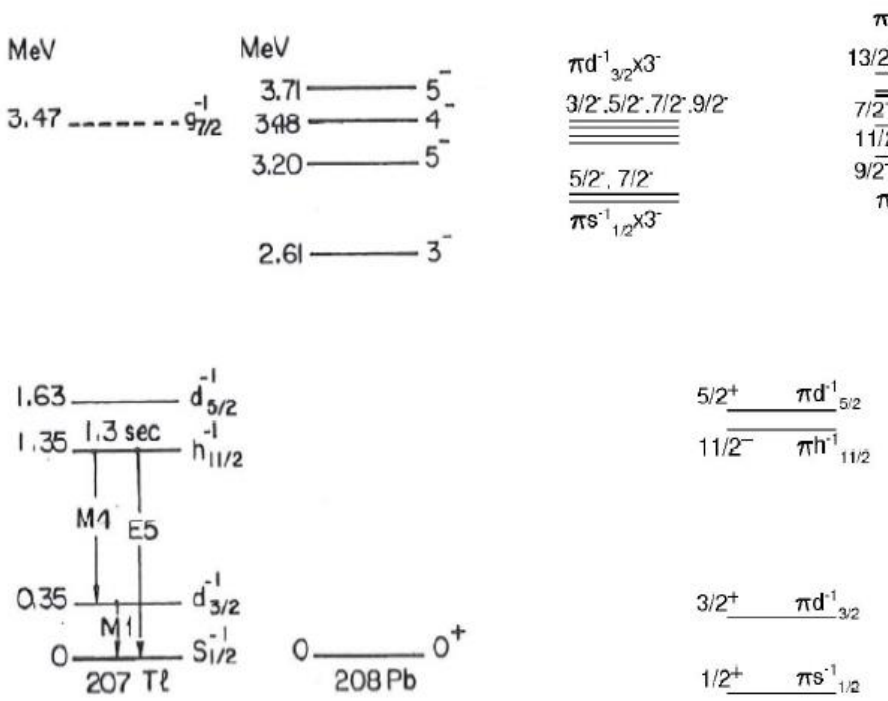
The IDS workhorses: 4 HPGe clovers (+ 1 Miniball Cluster)

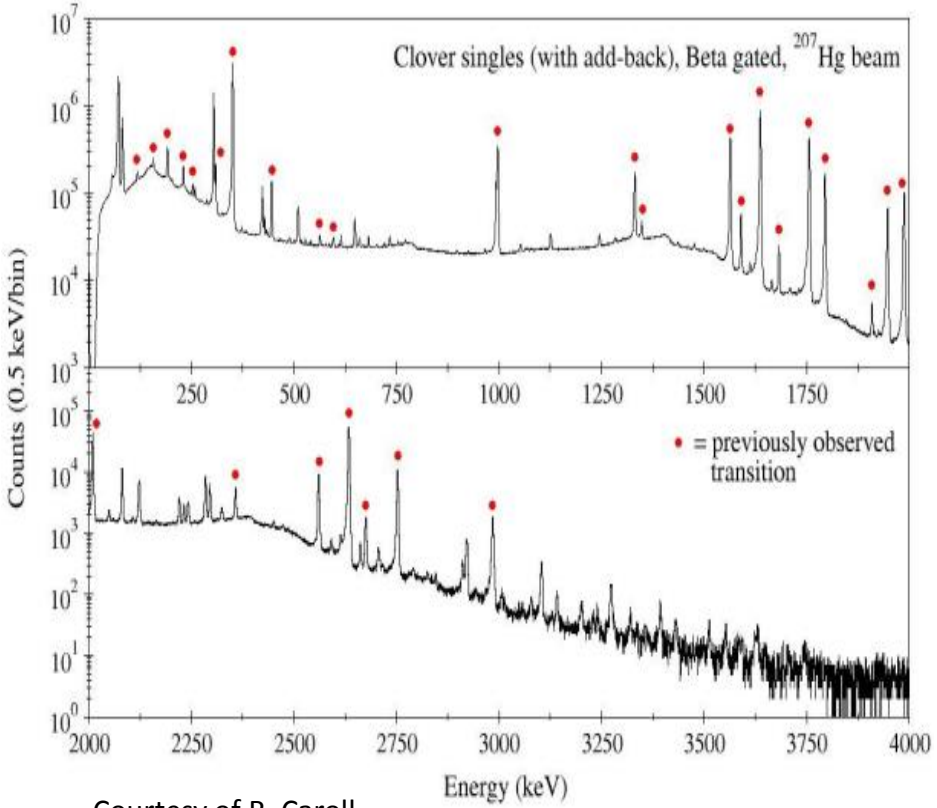




- Leuven Tape collection
- 4 Ge Clovers at Backward angles
- 1 Miniball Detector (triple cluster)
- 3 plastic scintillators: 30%

Core breaking and octupole low-spin states in ^{207}Tl





Courtesy of R. Caroll

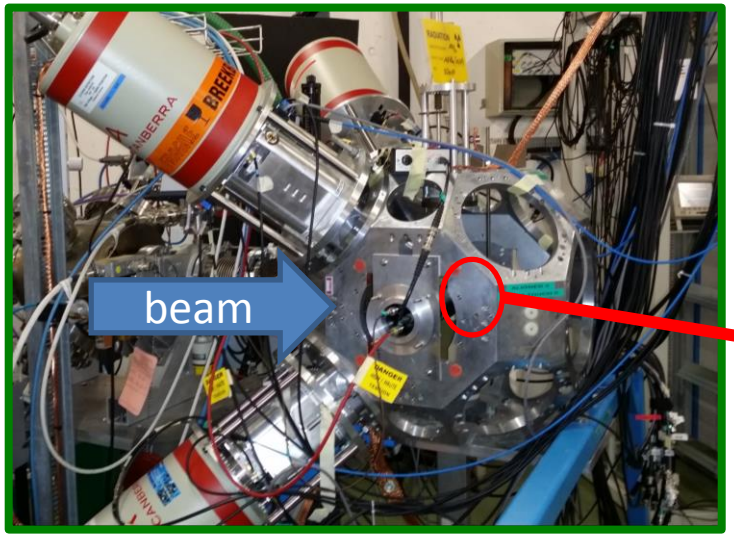
Spokesperson: Zsolt Podolyák (Univ. Surrey)

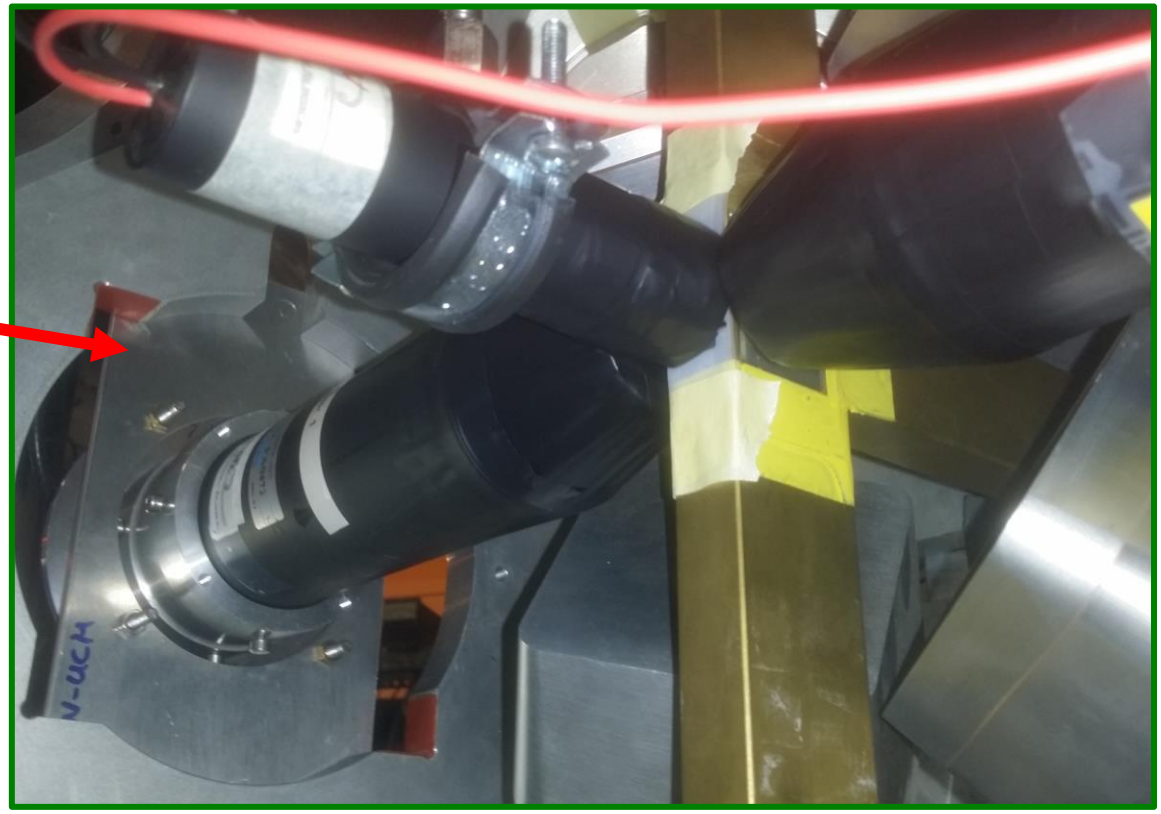
Physics:

- **Low-spin level structure** of the ^{207}Tl by β-decay of ^{207}Hg
- Breaking of the neutron or proton core
- Collective octupole phonon coupled to the single proton hole

Gamma lifetime measurements @ IDS

Life Time Measurements





- Implantation on Tape
- 4 Ge Clovers at Backward angles
- 1-3 $LaBr_3$
- 1-3 beta plastic scintillator

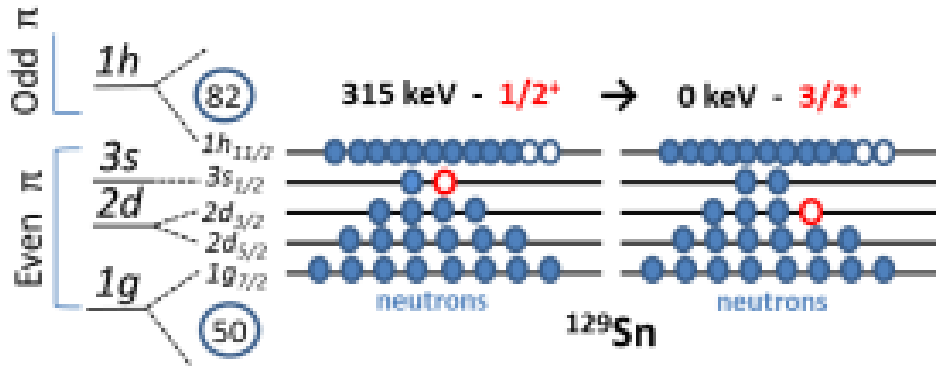
2014: -Fast-timing commissioning experiment (C. Sotty, L.M. Fraile)
-Study of octupole deformation in neutron-rich Ba isotopes populated via β-decay (G. Benzoni, H. Mach)

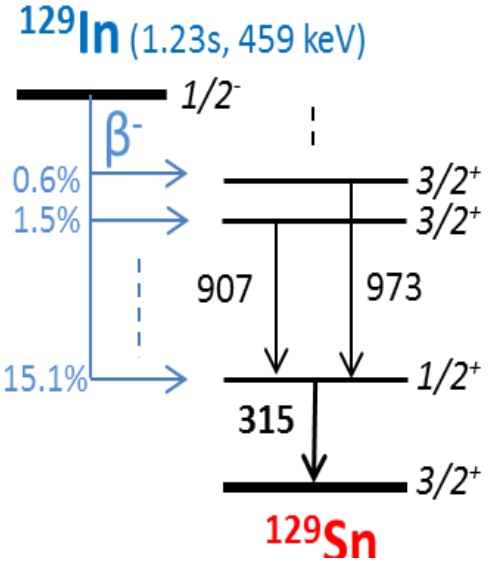
Study of the ^{129}Sn structure populated in the beta decay of ^{129}In

Physics:

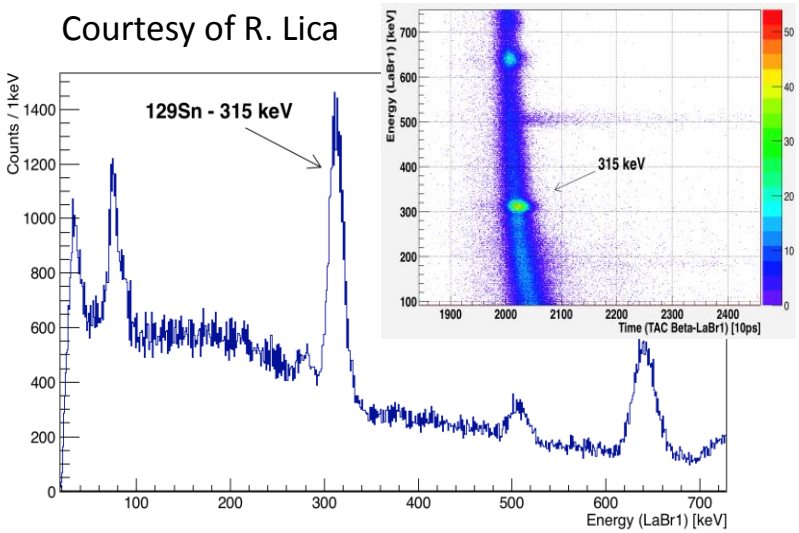
- $3s_{1/2} \rightarrow 2d_{3/2}$ **M1 l-forbidden**

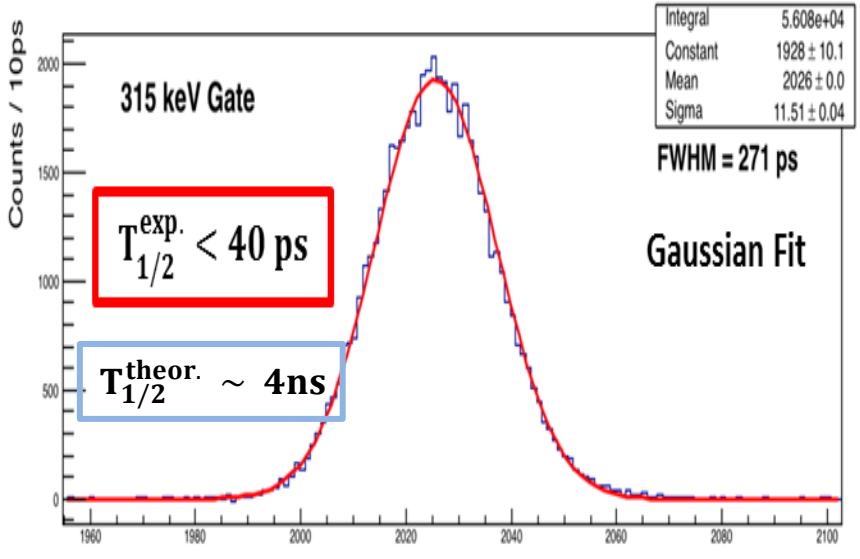
  Test for **M1 effective operators** near shell closure





Courtesy of R. Lica

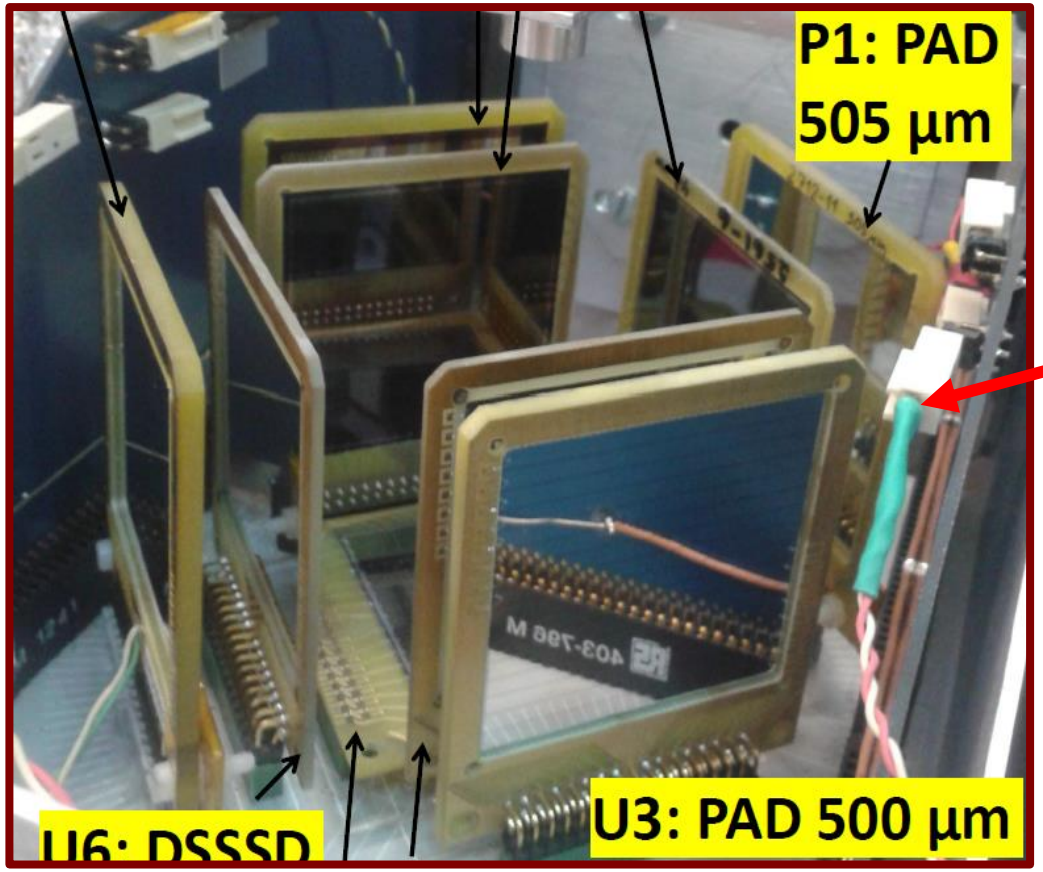


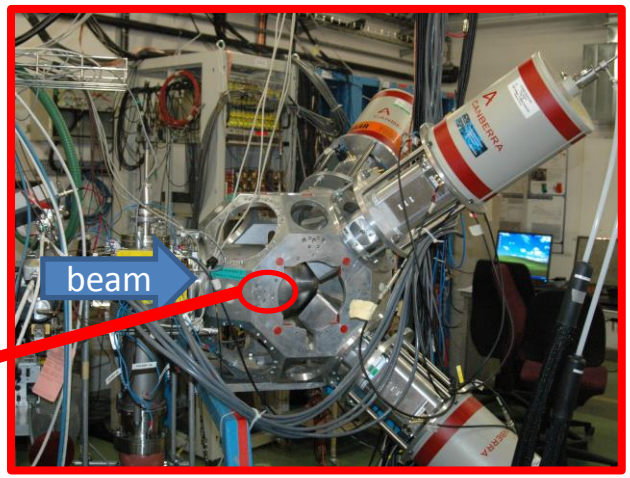


Shell Model: A. Gargano Private communication

Delayed charged particle emission

Charged Particle Spectroscopy





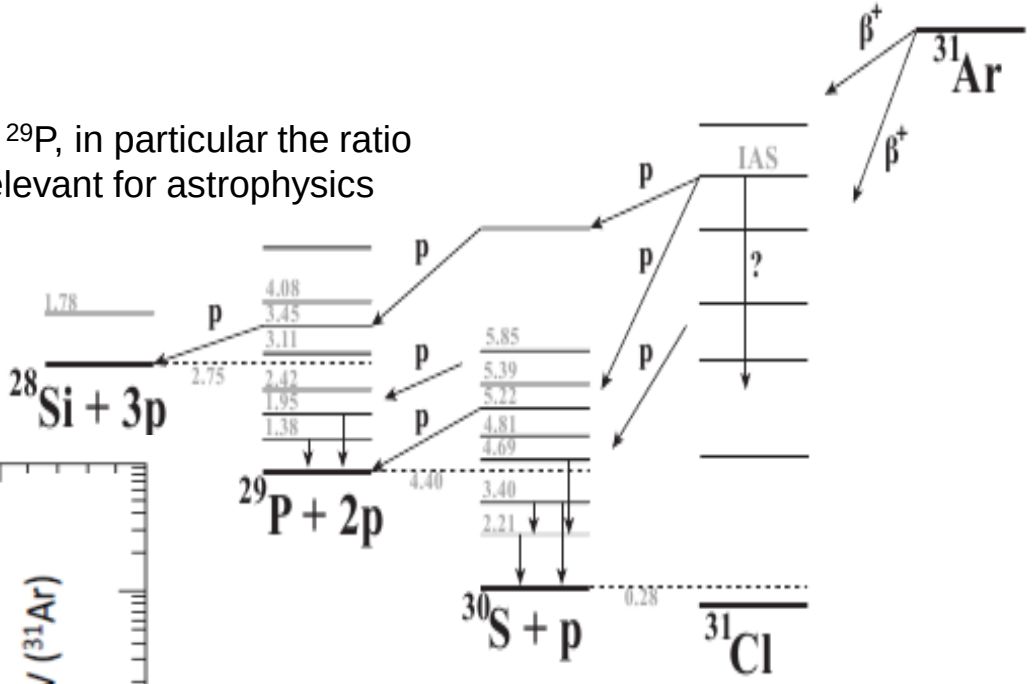
- Implantation on C foil
- 4 Ge Clovers at Forward angles
- Si box: 6 DE-E telescopes (70%)

2014: -β-3p spectroscopy and p-γ width determination in the decay of ^{31}A (H.O.Y Fynbo, G.T. Koldste, B. Blank)

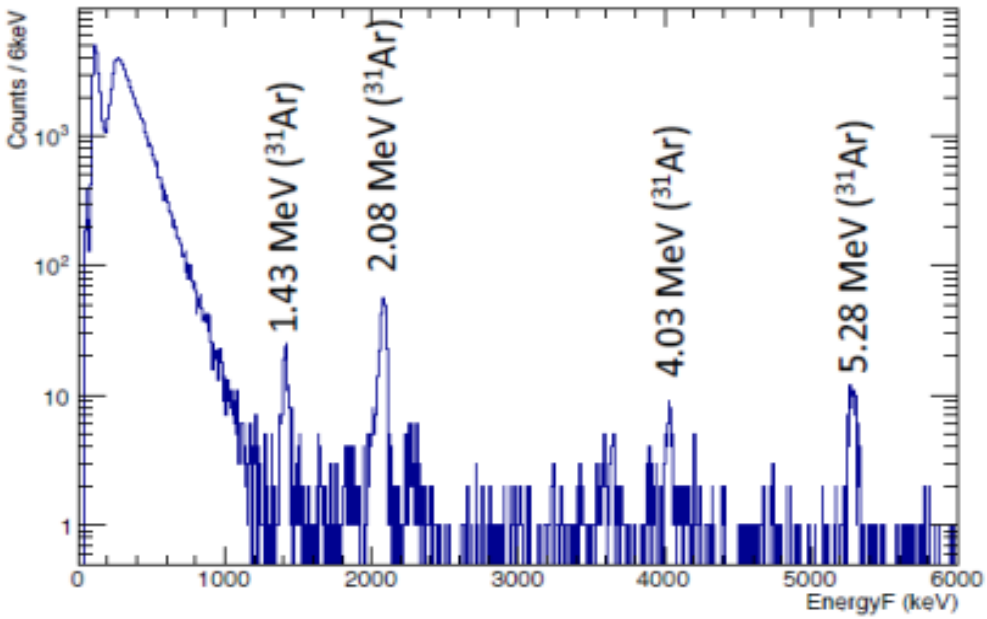
-Experimental investigation of decay properties of neutron deficient $^{116-118}$Ba isotopes and test of $^{112-115}$Ba yields. (U.D. Pramanik O. Tengblad)

β-3p spectroscopy and p-γ width determination in the decay of ^{31}Ar

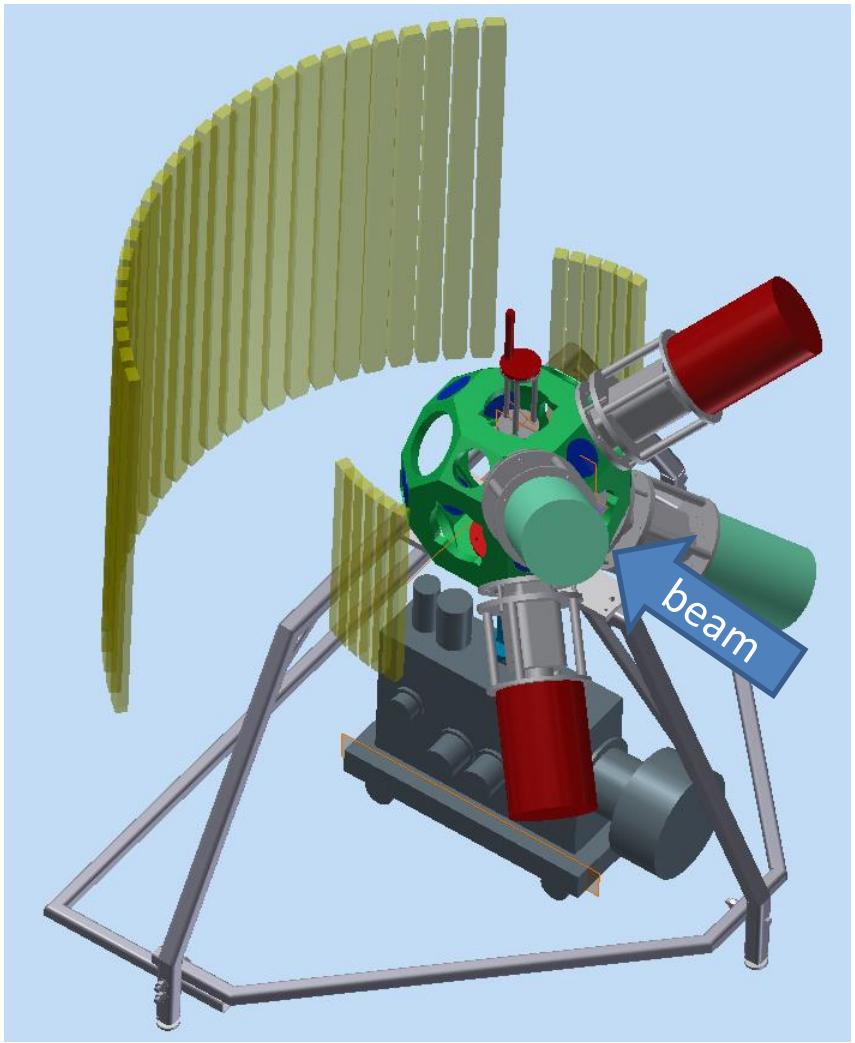
- **Spokesperson:** H. O. U. Fynbo (Univ. Aarhus), G.T. Koldste (Univ. Aarhus), Bertram Blank (CENBG)
- **Physics:**
  - **β-delayed 3p-decay branch**
  - Information on the resonances of ^{30}S and ^{29}P, in particular the ratio between the proton and γ partial widths relevant for astrophysics



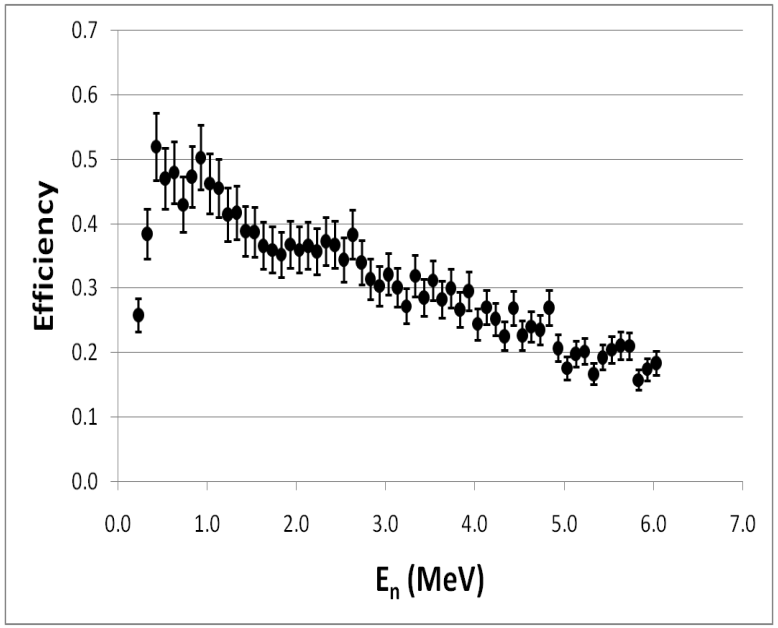
Proton energy spectrum



Beta delayed neutron spectroscopy at the ISOLDE decay station

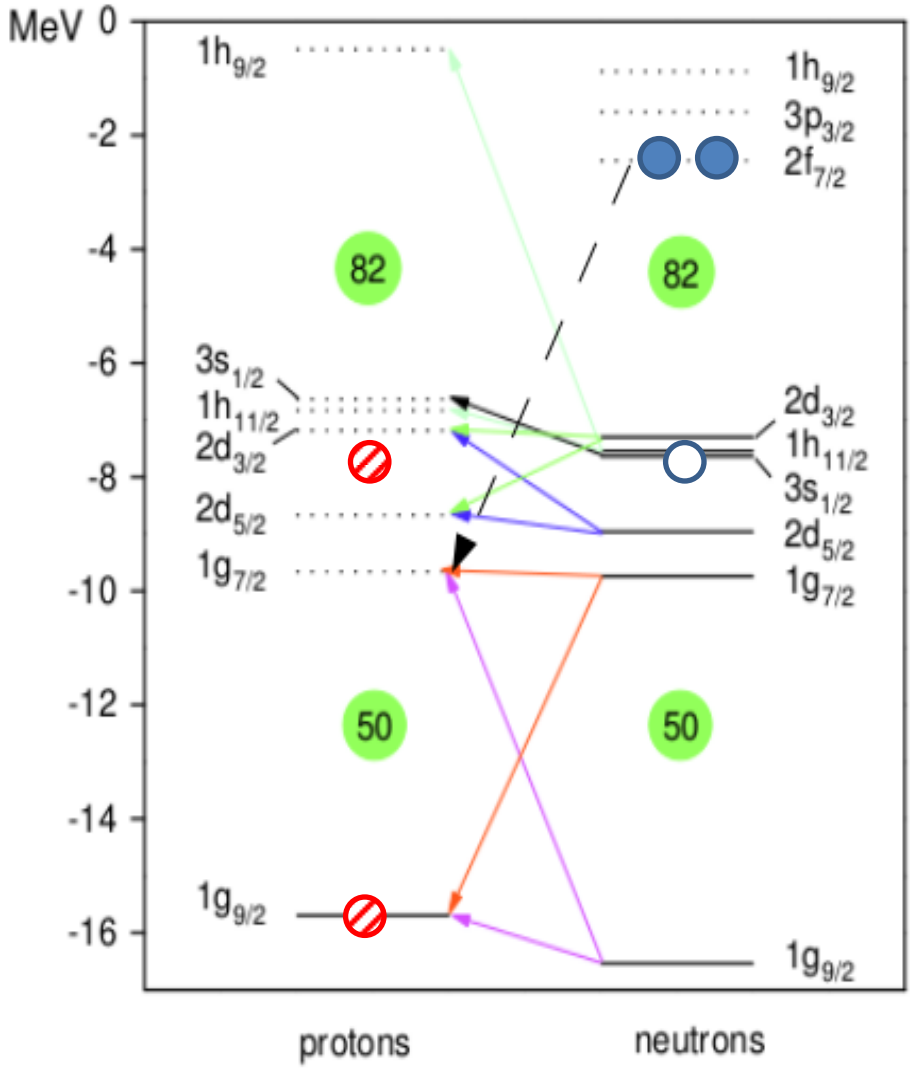


- 4 clovers, 4% efficient @ 1MeV
- Newly developed ISOLDE neutron detector
  - 45% efficiency/bar @ 1MeV
  - Ω = 21.7% of 4π
  - 60% β-trigger efficiency
  - 5.9% total efficiency @ 1MeV



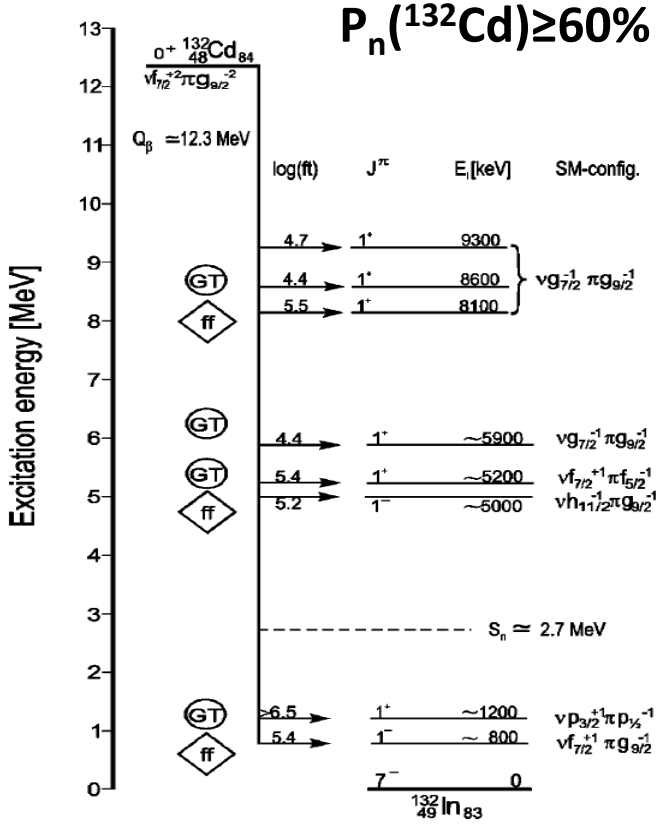
Beta-decay of Cd isotopes beyond N=82 -- ^{132}Cd

spokespersons: MM, R. Grzywacz



- FF and GT strength separated by N=82 shell ga
- Neutron distribution → *ν-gdh* single particle states

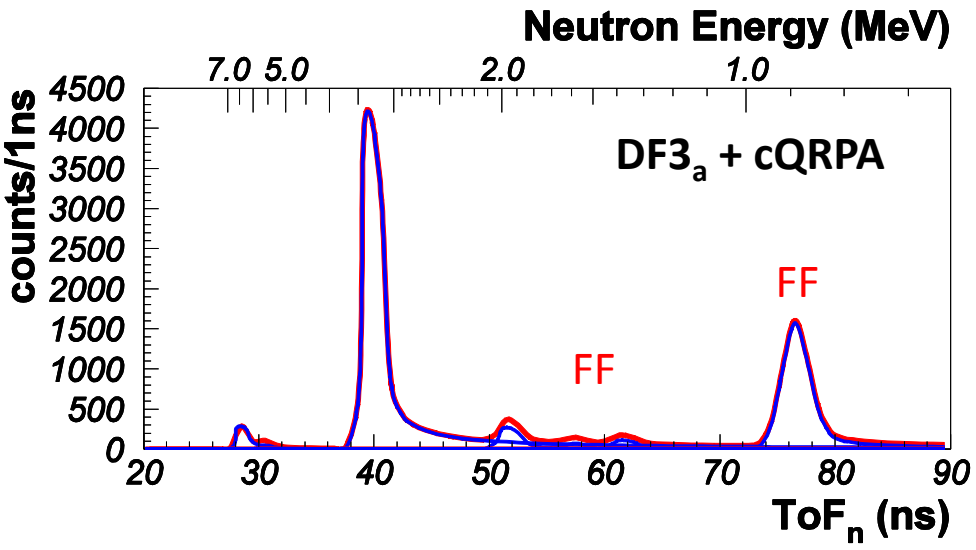
$P_n(^{132}Cd) \geq 60\%$

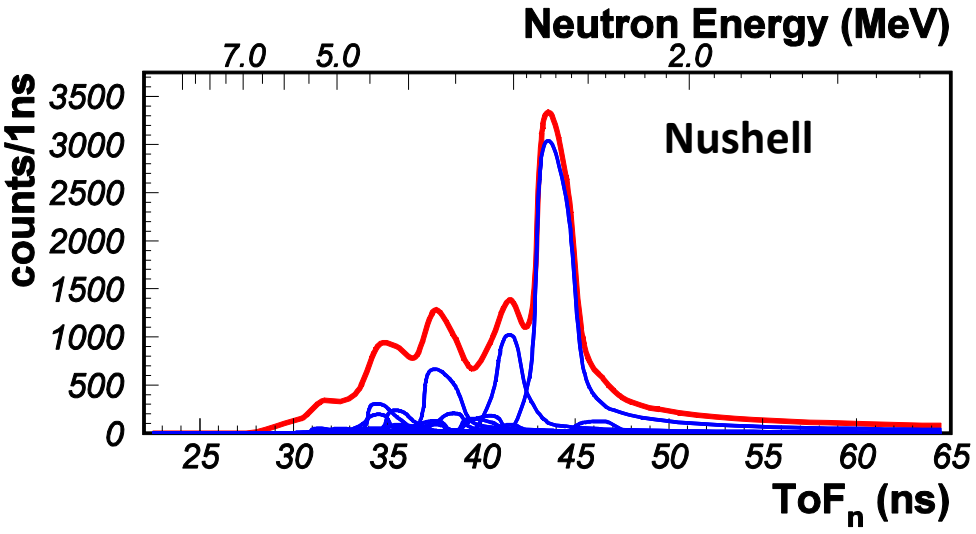


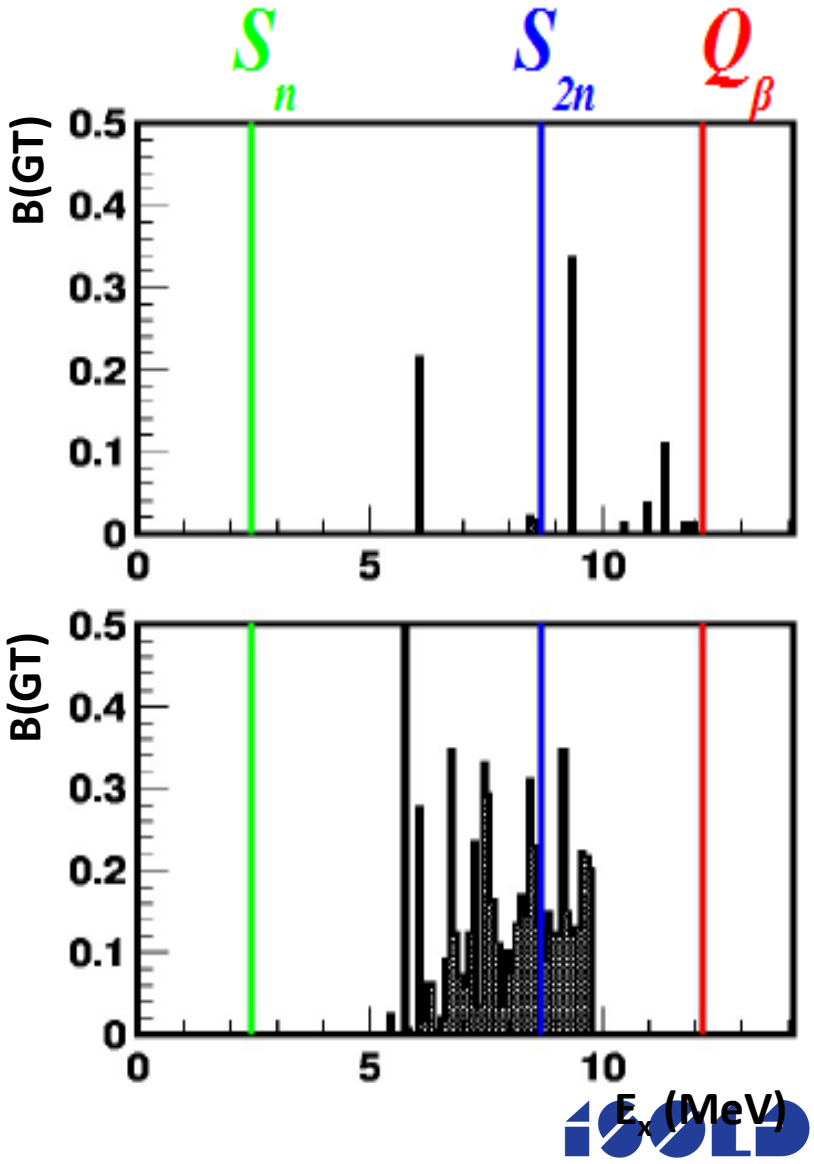
M. Hannawald et al., PRC 62, 054301 (2000)

^{132}Cd @ ISOLDE

I.N. Borzov, Private communication

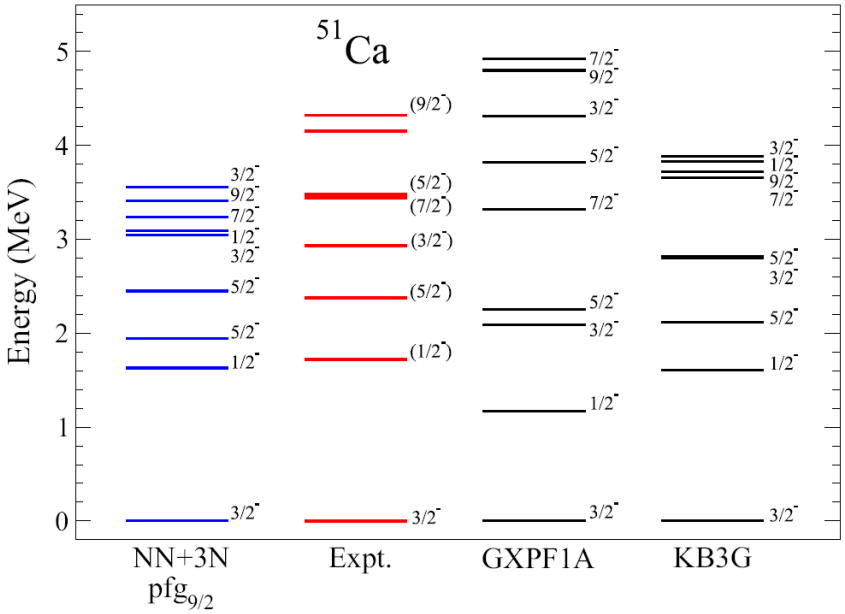




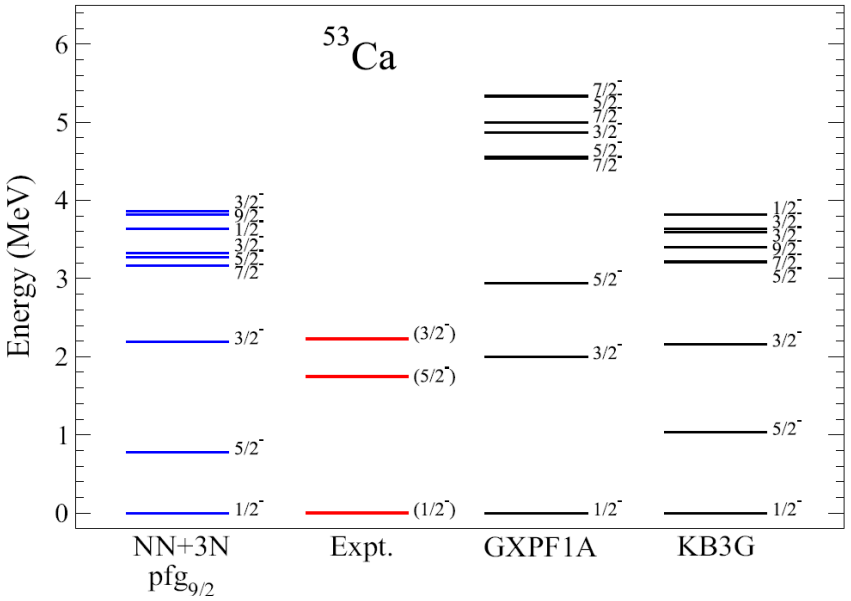


Study of neutron-rich $^{51\text{-}53}$Ca isotopes via beta-decay

Spokespersons: A. Gottardo, MM

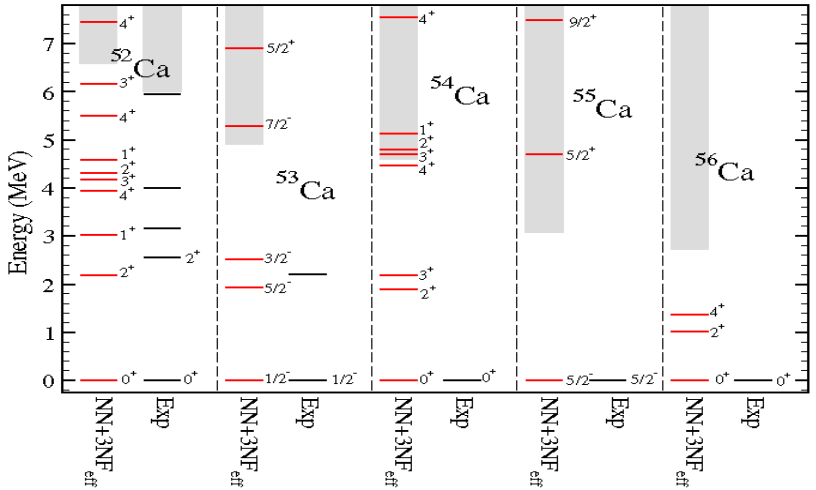


J. D. Holt et al., PRC 90, 024312 (2014)

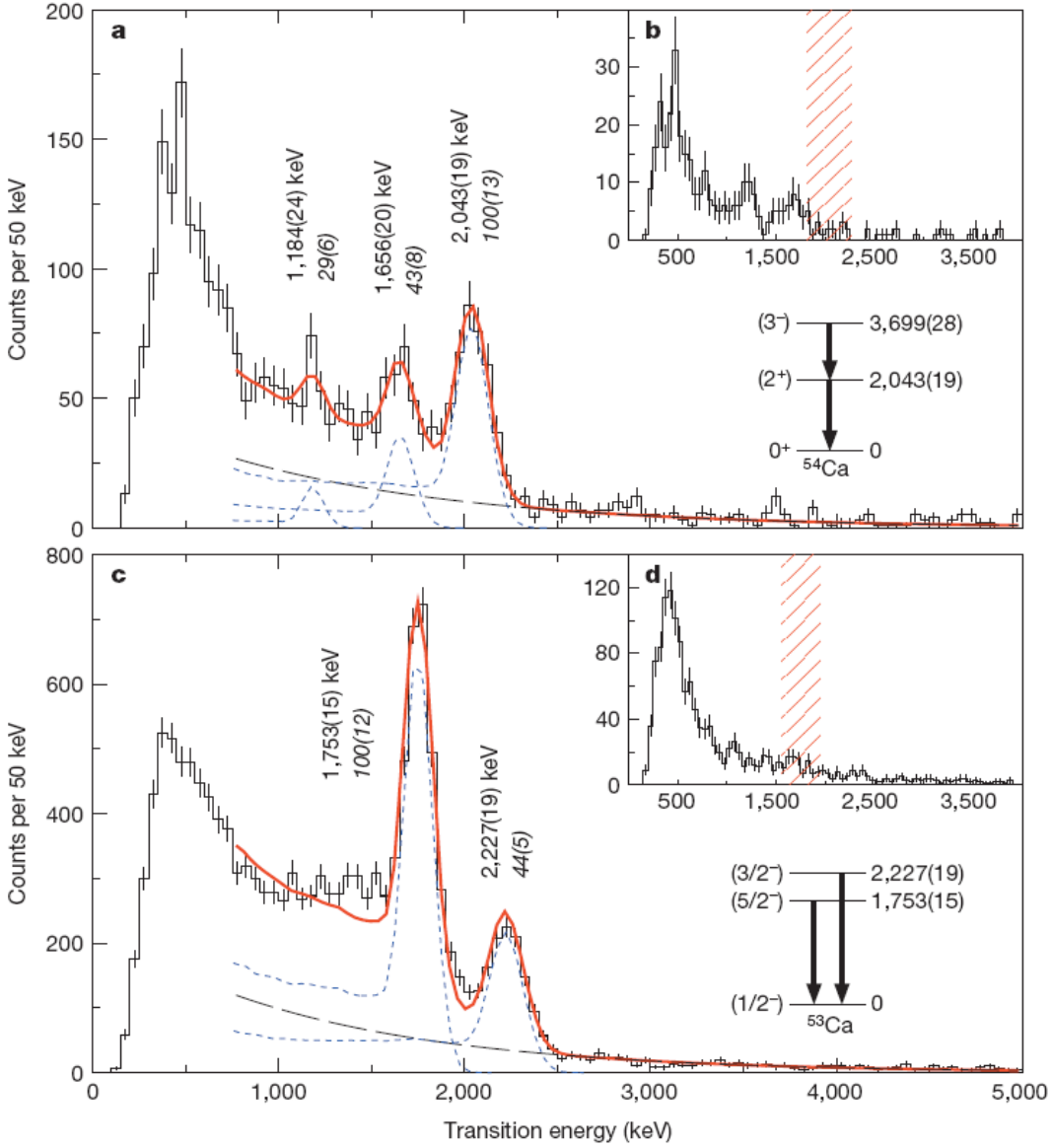


Different prediction going towards the N=34 for the $f_{7/2}$ gap (different 3N forces + coupling to continuum)

G. Hagen et al., Phys. Rev. Lett. 109, 032502 (2012)



The N=34 closure and ^{53,54}Ca



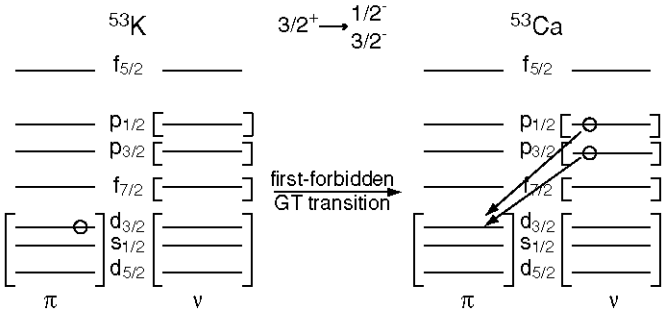
D. Steppenbeck et al., Nature 502, 207 (2013)

F. Wienholtz et al., Nature 498, 346 (2013)

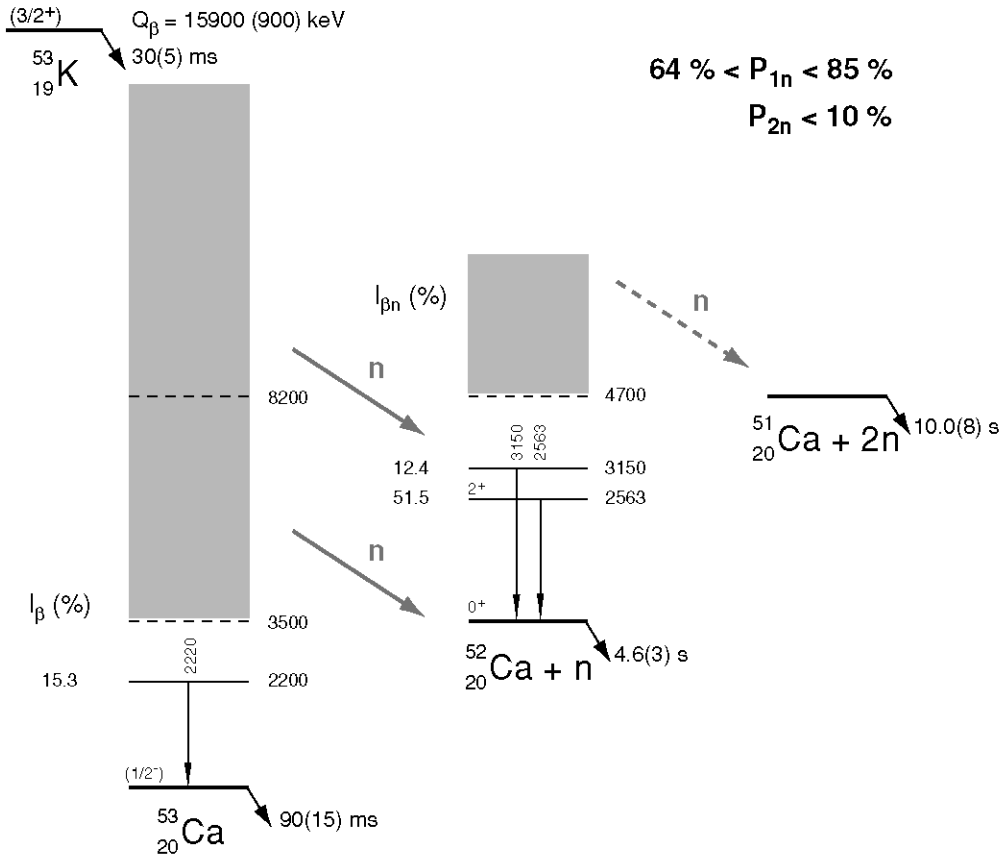
^{54}Ca : the 2^+ energy and the mass indicate a subshell closure

^{53}Ca : understanding single-particle energies going towards N=34: $\nu p_{1/2} - \nu f_{5/2}$ gap

Past ^{53}Ca measurement



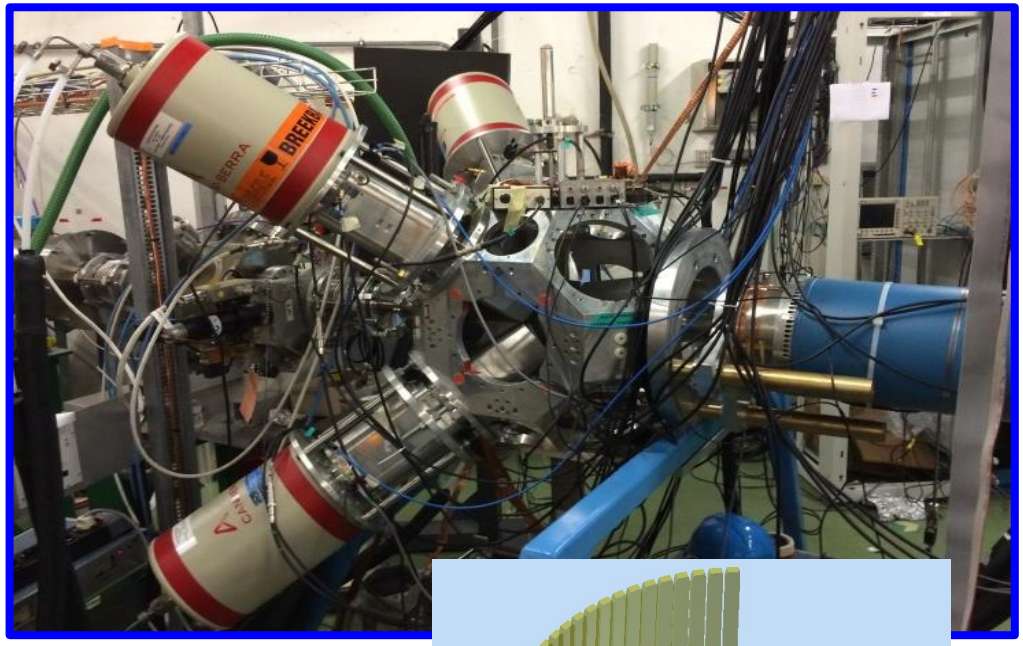
- The GT decay should populate the $\pi f_{7/2}$ shell -> we expect $\nu f_{7/2}^{-1}\ \pi f_{7/2}^{1}$ states at 8-10 MeV: 2n emission
- FF could also lead to $\nu p_{1/2}^{-1}\ \nu p_{3/2}^{-1}\ \nu f_{7/2}^{-1}$ states (closed Z=20)

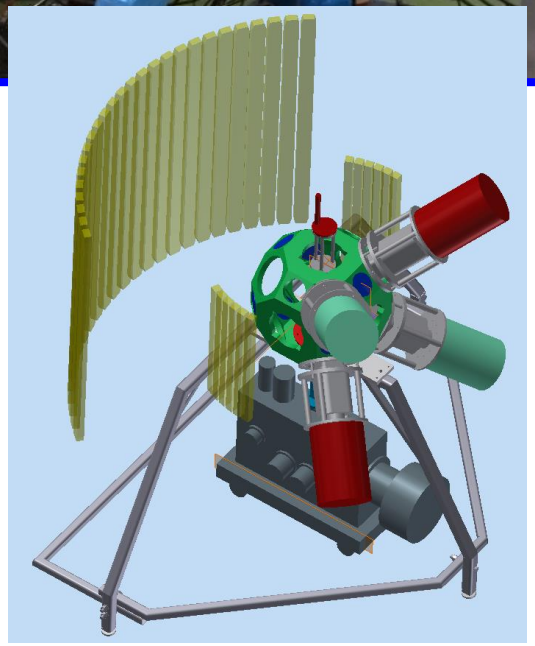


F. Perrot et al., Phys. Rev. C 74, 014313 (2006)

Not enough statistics to reconstruct the level scheme

Summary





- Nuclear structure from <u>radioactive</u> nuclei:
  - Decay properties: nuclear astrophysics/reactor physics
  - Properties of the daughter: Selective/clean probe of excited states
- IDS provides minimum infrastructure for decay experiments at ISOLDE:
  - 4 (+1) HPGe clovers
  - Beta triggers
  - Tape station
  - Digital data acquisition
- Flexible design for specialized setups:
  - Gamma lifetime measurements
  - delayed charged particle/neutron emission

Acknowledgements

Thanks for your attention

The IDS Collaboration

Experimental setup: Electronics and DAQ

- TDR - DAQ for IDS:
  - **TDR** – **T**otal **D**ata **R**eadout (Daresbury, UK), widely used at JYFL, chosen for **ISOLDE IDS - phase I**.
  - Channels are **read out asynchronously** in singles mode and each data item is **time-stamped with an external clock** .
  - **3 x VHS-ADC** : 16 ch, 105 MSPS, 14-bit ADC (virtex4 FPGA) - could be available on loan from JYFL
  - Capable to handle rates **~30kHz/ch** (DC beam)
  - **Event building and analysis** has to be done entirely in the software **post-processing** the data stream.
  - Data recording framework : **MIDAS**

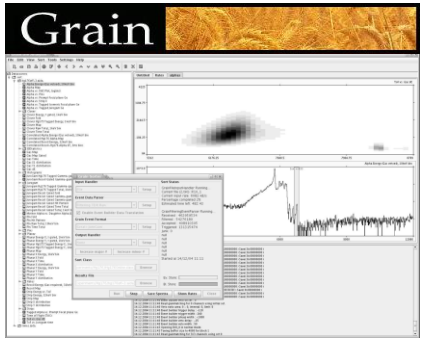
HPGe: 19 ch (max 25, phase II)
LaBr3: 6 ch
Plastic: 3 ch
TAC: 15 ch
Total: 43 ch (48 ch available)

+ ISOLDE status (T1, T2, tape, laser…)

Lyrtech VHS-ADC

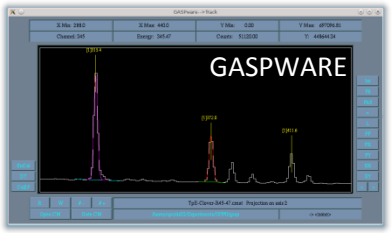
- GRAIN – data analysis software (ONLINE):
  - Developed at JYU to be used with the novel Total Data Readout (TDR) data acquisition system.
  - **A flexible and efficient event parser** and the accompanying software framework written entirely in **Java**.

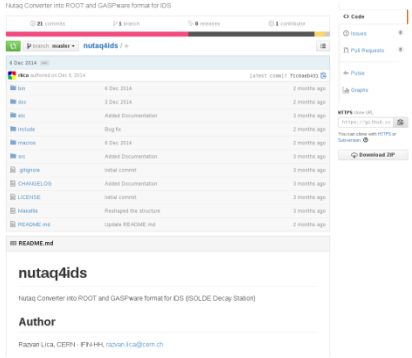
https://trac.cc.jyu.fi/projects/grain



P. Rahkila, NIM A 595, 637 (2008)

- N4ids - data analysis software (ONLINE/OFFLINE):
  - **Conversion code** developed at CERN written in **C++**
  - **Analysis** with **GASPWARE** or **ROOT**





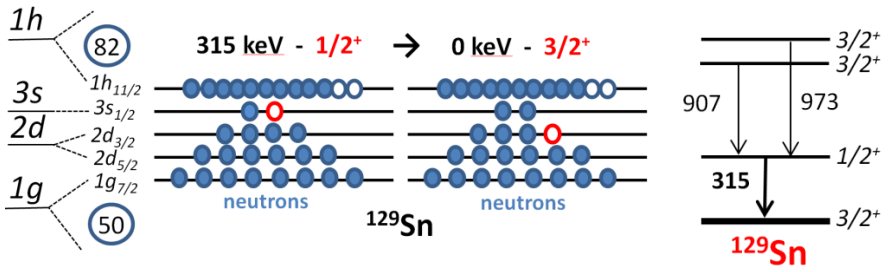
https://github.com/rlica/nutaq4ids

Courtesy of R. Lica

Experimental results interpretation

A factor **100** difference between theory and measurement

$T_{1/2}^{theor.} \sim 4ns$ >> $T_{1/2}^{exp.} < 40\ ps$



What are the implications?

A major change in the shell structure might not reproduce well the energy levels

$E^{theor}(1/2+) = 294$ keV ≈ $E^{exp}(1/2+) = 315$ keV

A slightly different from zero **M1 effective operator** for neutron holes greatly improves the agreement without changing any other matrix elements

$T_{1/2}^{theor.}$(<d3/2|M1|s1/2>=0.1) ~ **120 ps**

< d3/2| M1| s1/2> - already known for proton particles (= 0.14)
- unknown for neutron holes in the ^{132}Sn region

Our measurement can provide the first estimation for the value of the M1 effective operator

A. Gargano, Private Communication

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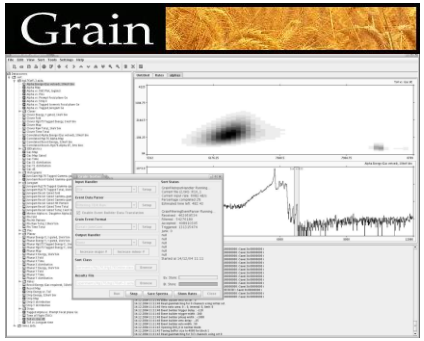

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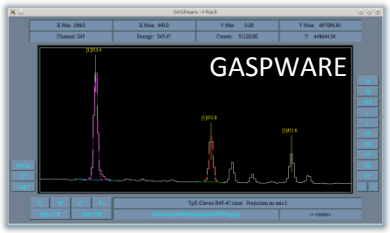
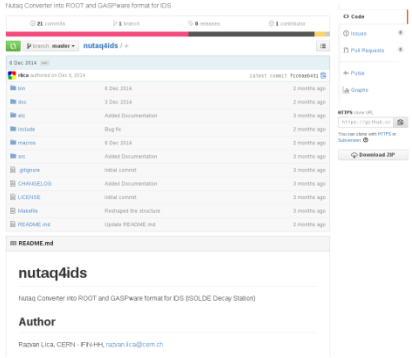


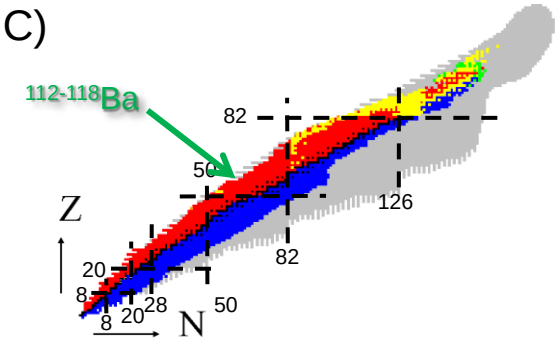


https://github.com/rlica/nutaq4ids

Courtesy of R. Lica

IS545: Experimental investigation of decay properties of neutron deficient $^{116\text{-}118}$Ba isotopes and test of $^{112\text{-}115}$Ba beam counts

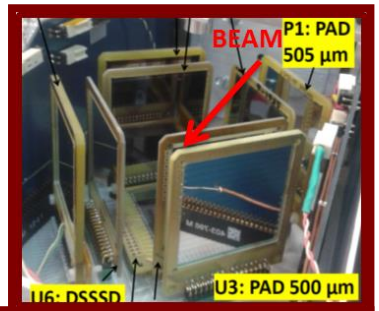
- **Spokesperson:** U.D. Pramanik (Saha INP), O. Tengblad (CSIC)
- **Physics:**
  - Study of n-deficient $^{116\text{-}118}$Ba on the vicinity to proton dripline
  - Proton emission, width of the resonant state
  - **Beam development for neutron-deficient $^{112\text{-}115}$Ba nuclei**

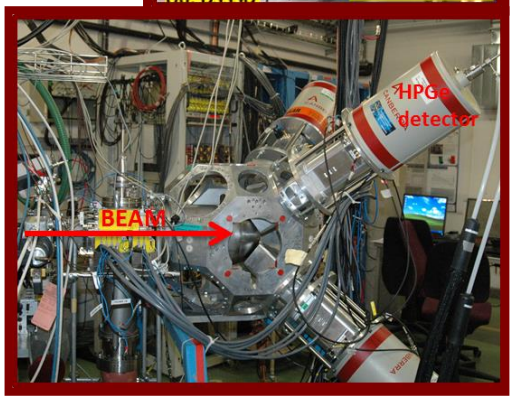


- **Set-up and Methodology:**
  - **LaC target (nano-structured)**
  - 4 HPGe Clover detectors at forward angles
    + Si box (5 DSSSD's, 4 Pad's)
  - ISOLDE MBS and IDS Nutaq use in parallel
  - 165 ch: Mesytec preamplifiers (2xMPR64, 2xMPR32)
  - Mesytec STMR16+ shapers

Same

Charged Particle Spectroscopy

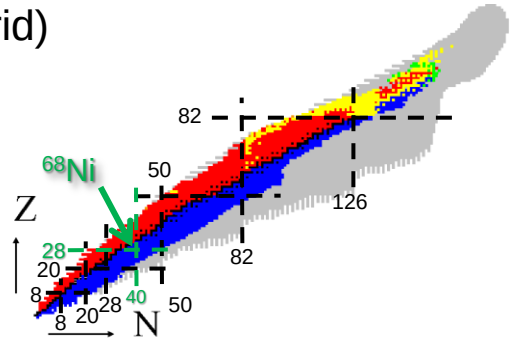




- **Preliminary Results:**
  - **LaC target (nano-structured)** led to **better release** specially for Ba
  - Injection of **CF4** gave **pure Ba** (free from Cs)
  - **Estimated production 31 ^{115}Cs/s**
  - Further data taken (not analyzed):
    A=138(^{119}Ba+^{19}F), A=136(^{117}Ba+^{19}F) and A=133(^{114}Ba+^{19}F).

IS590: Characterization of the low-lying 0^+ and 2^+ states of ^{68}Ni

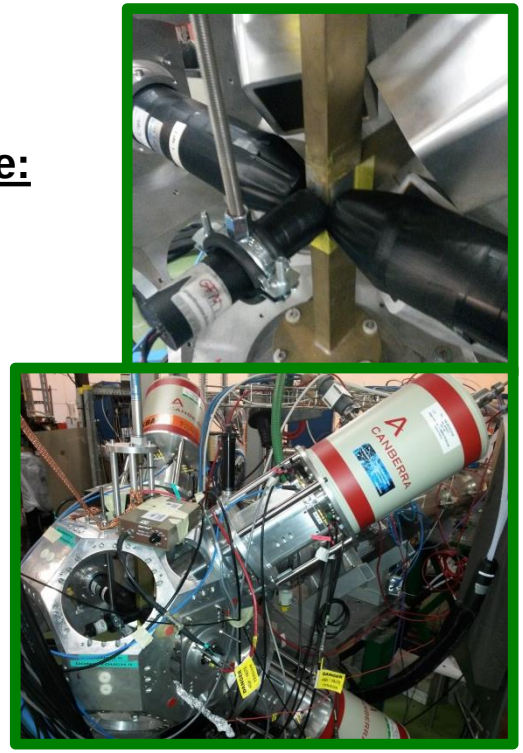
- **Spokesperson:** C. Sotty (KU Leuven-IKS), L. Fraile (Univ. Madrid)
- **Physics:**
  - **Detailed spectroscopy data of the low-spin states of ^{68}Ni (triple pairs of $0^+/2^+$ states)**
  - Gamma branching ratios of the 0^+ and 2^+ states and E0 transition strength



- **Low 68Mn yields (<1pps) → Cancelled**

- **Yield tests to identify the origins of such low production rate:**
  - ^{64,66}Mn isotopes
  - Two different UCx targets (#509 and #512)
  - With/without neutron converter
  - **Target lower performing**
  - → requested 5pps for the production of ^{68}Mn

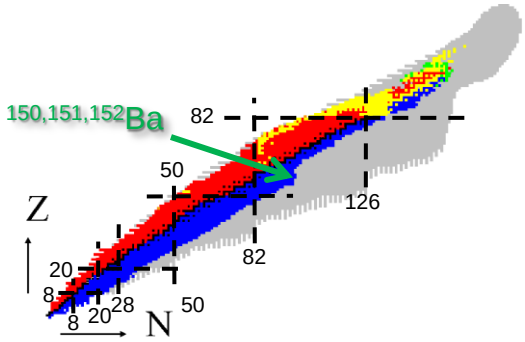
Life Time Measurements



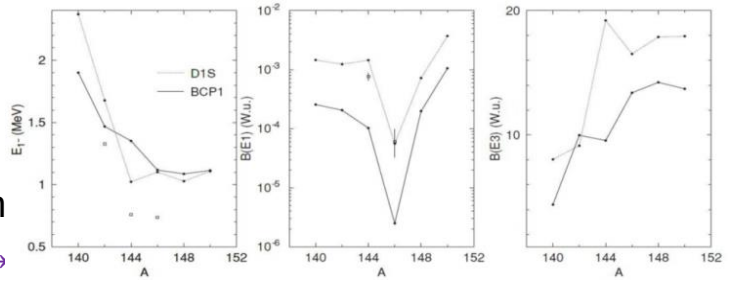
➢ **Commissioning of the fast timing configuration with the ^{129}In decay**

IS579: Study of octupole deformation in neutron-rich Ba isotopes populated via β-decay

- **Spokesperson:** G. Benzoni (INFN Milano), H. Mach(NCBJ)
- **Physics:**
  - β-decay of ^{150,151,152}Cs to study Ba daughter nuclei
  - **Evolution of the octupole deformation** across the isotopic chain
    Insight via the B(E1), B(E3) transition strength
  - **Astrophysical process:**
    - **Halflives** necessary to determine the correct timescale and waiting points
    - P_n values determine the **r-process path** and influence on the fission rates



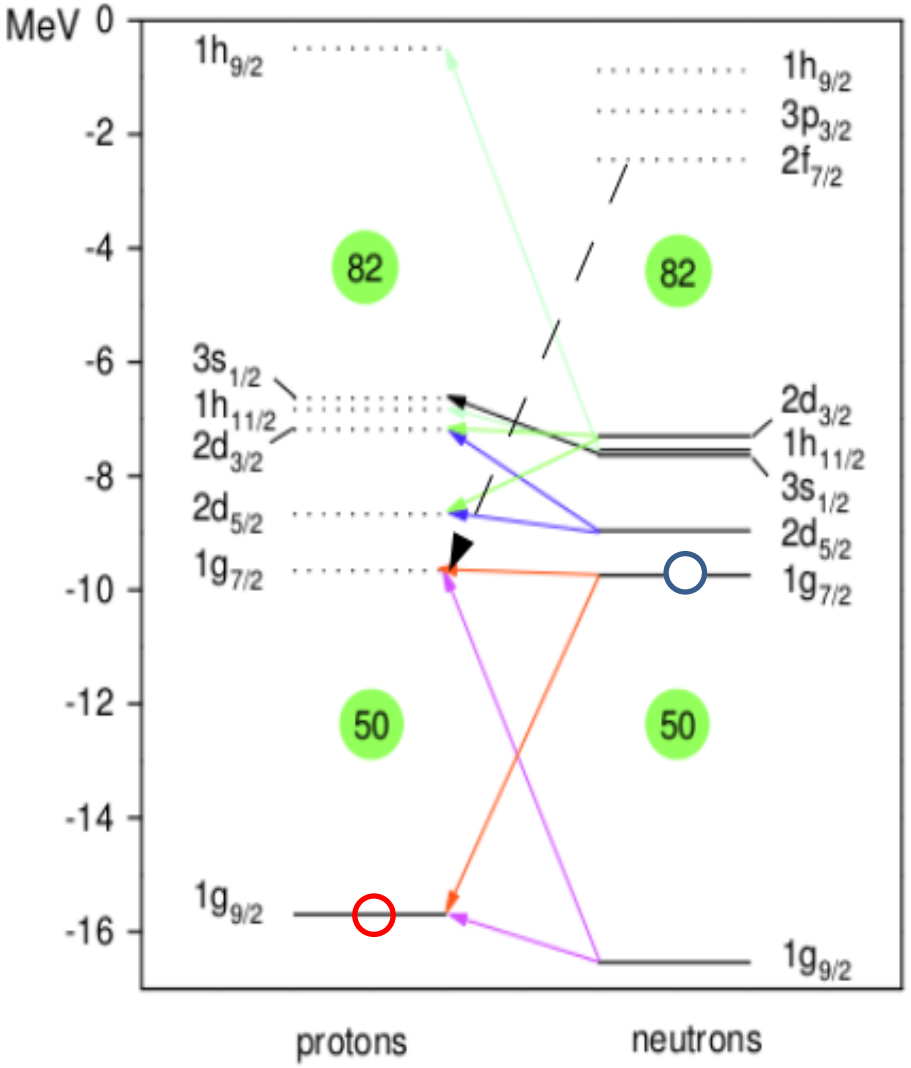
HFB mean-field with axially symmetric octupole moment as a constraint



- **Preliminary Results:**
  - ^{148,149}Cs → ^{148,149}Ba decay chains used as referen
  - **Half of the shifts dedicated to study the ^{150}Cs→**
  - **Yields lower than expected (~1.2 ^{150}Cs /μC)**
  - **Lifetimes, delayed n-emission probabilities** will be extracted thanks to:
    detailed spectroscopy and γ-γ coincidences and fast-timing technique

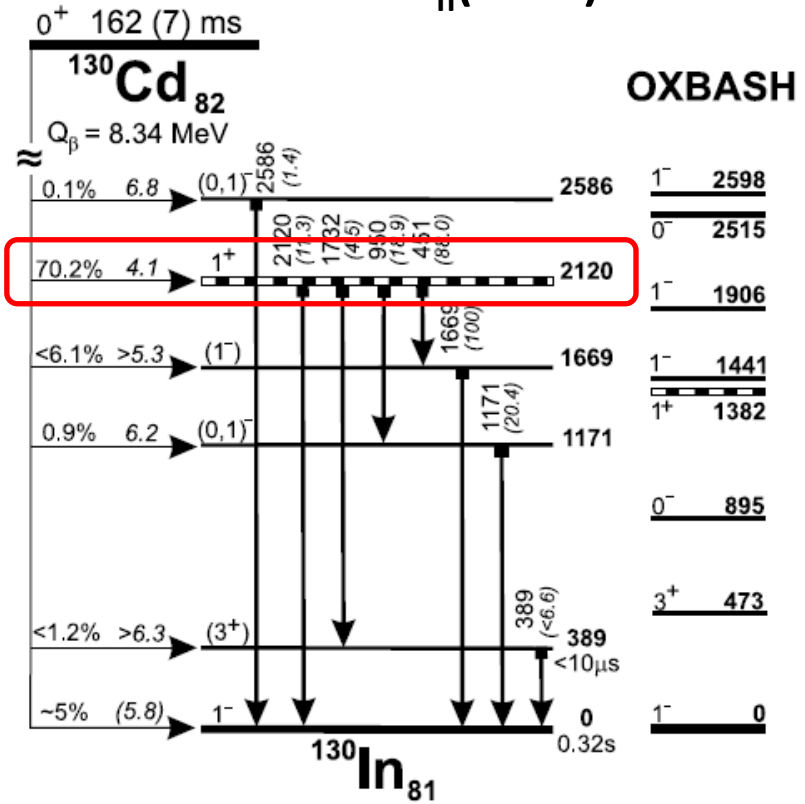
Beta-decay of Cd isotopes around N=82

^{130}Cd



- Low energy states in In driven by SPEs

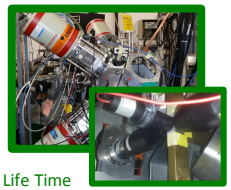
$P_n(^{131}Cd)=3.5\%$



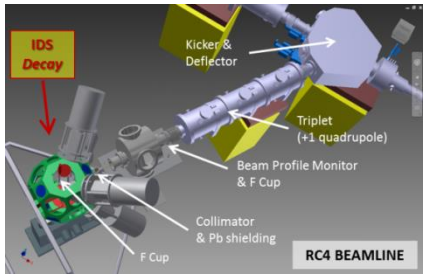
I. Dillmann et al., PRL. 91, 162503 (2003).

IDS Status Report Campaign 2014 and future

- **Campaign 2014 (Phase-I.0):**
  - **Setup:**
    - Phase-I : 3 configurations operational
    - RC4 beamline operational
  - **Experiments:**
    - 6 proposals approved, 5 experiment performed,
    - Data analysis on going but already promising results


Life Time Measurements


High efficiency Gamma Spectroscopy

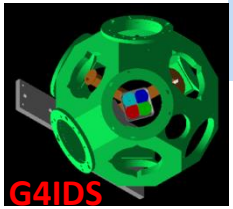


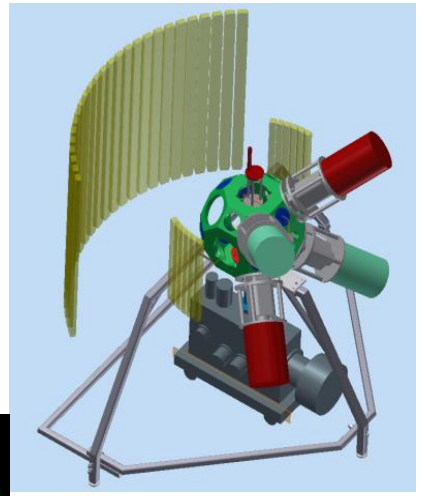

Charged Particle Spectroscopy

- **Campaign 2015 (Phase-I.1):**
  - **Setup:**
    - Same configurations available
    - Same electronics and DAQ
    - Upgrade beam diagnostics
    - Upgrade of the tape station (new motor and controller)
    - Coupling to VANDLE (run with its own electronics/DAQ)
  - **Experiments:**
    - INTC (October 2014): 1 proposal approved ($^{51-53}$Ca)
      1 proposal under clarification ($^{130-132}$Cd)
  - **G4IDS:** Geant4 code to support the proposals and analysis


Tape Station


Lyrtech VHS-ADC




IDS coupled with VANDLE

- **Phase-II (from 2016 onwards)**
  - **Setup upgrades:**
    - New implantation chambers (for α-decay, β-delayed fission, high-resolution electron spectroscopy studies)
    - New holding structure
    - Different DAQ system allowing a larger number of channels

IDS< &future