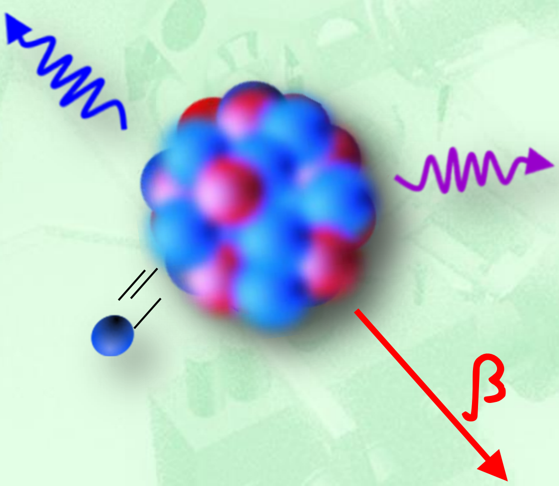
The New ISOLDE Decay Station (IDS)

Different Phases for Different Physics

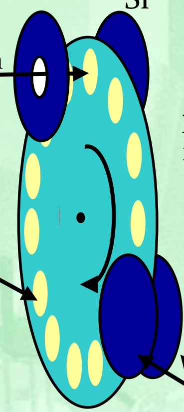
Sotty Christophe

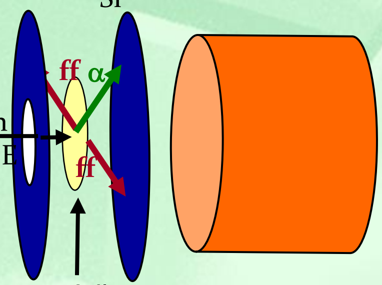
EGAN Workshop 2014

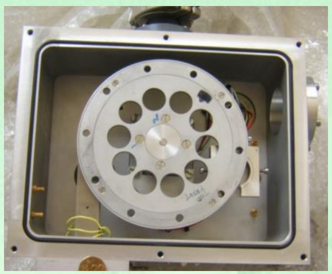


Previous decay setups used at ISOLDE

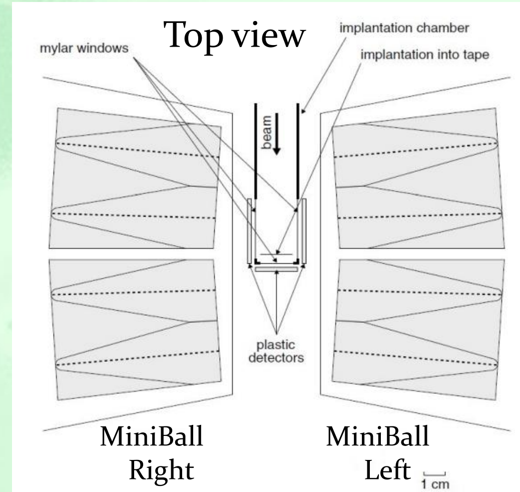
WINDMILL (α-decay)





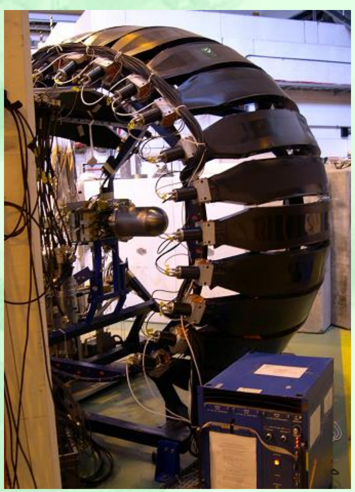


LISOL decay setup (ß-delayed spectroscopy)

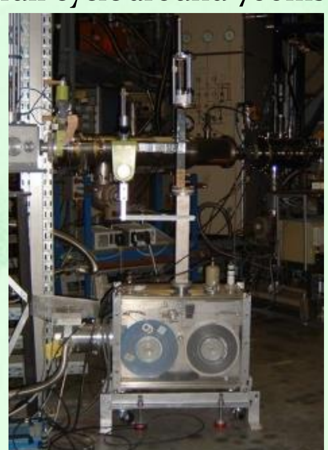


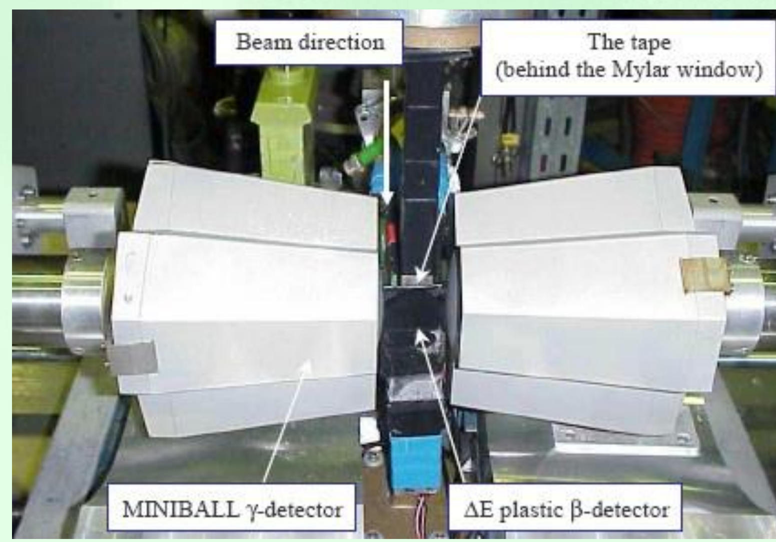
ε_γ	~ 6%
ε_β	~ 50%
ε_γ^{int}	~ 30%
G_γ	= 6
G_β	= 3
$S_{\beta,\gamma}(n)$	< 15%
$S_\beta(\gamma)$	~ 1-2%
$S_\gamma(\beta)$	> 50%

TONNERRE (neutron Spectroscopy - 2003)



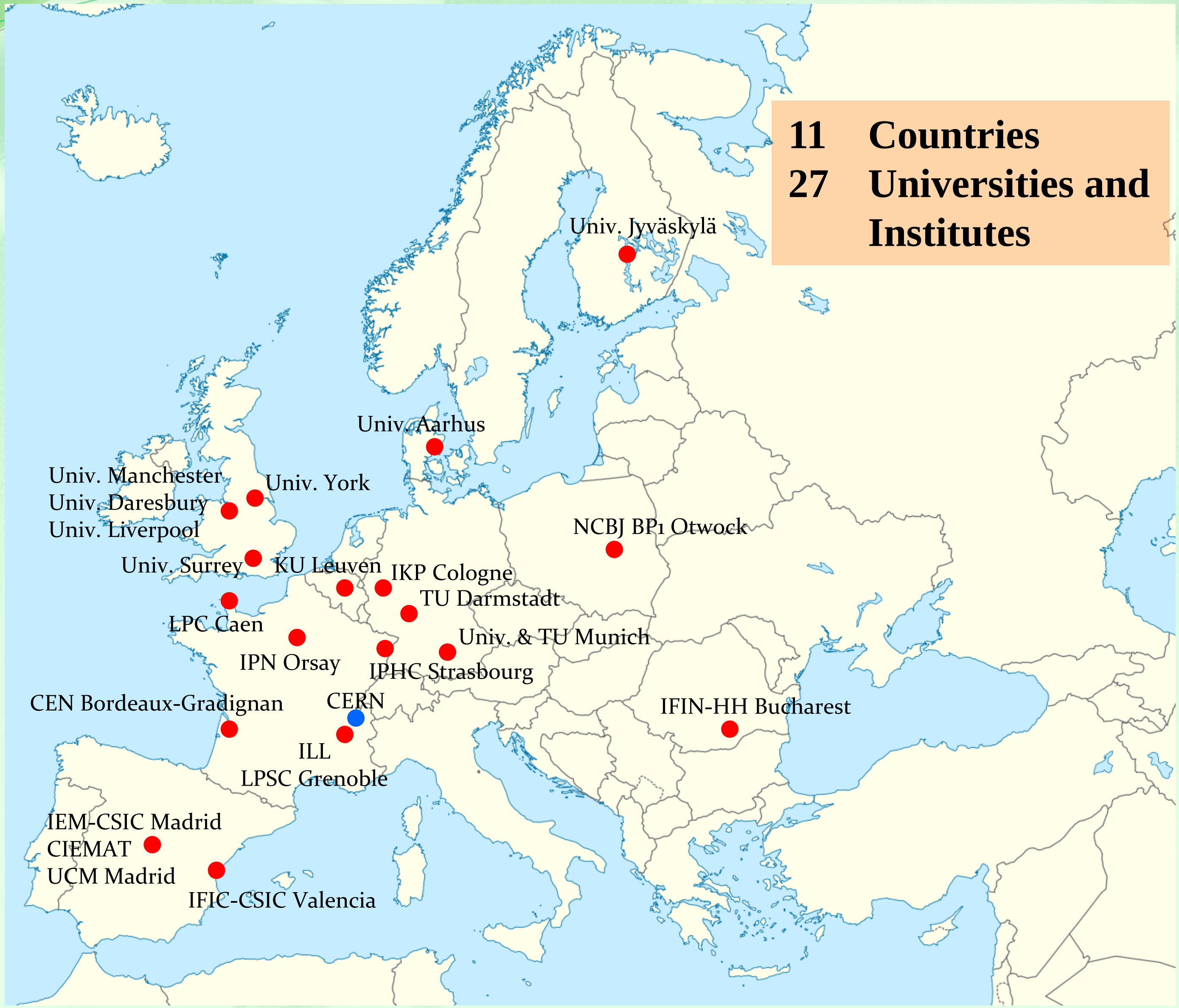
LISOL tape station
full cycle around 700ms





CLOSE GEOMETRY -> true summing effect

IDS setup at the ISOLDE Facility



BELGIUM (KU Leuven - IKS)

DENMARK (Univ. of Aarhu)

FINLAND (Univ. of Jyväskylä)

FRANCE (CEN Bordeaux-Gradignan; IPHC Strasbourg; LPC Caen; LPSC Grenoble; IPN Orsay; Univ. Paris Sud; ILL)

GERMANY (IKP - TU Darmstadt; IKP- Univ. zu Köln; Univ. zu München; TU München)

POLAND (NCBJ BP1 Otwock)

ROMANIA (IFIN-HH Bucharest)

SPAIN (CIEMAT Madrid; IEM-CSIC Madrid; IFIC-CSIC Valencia; UCM Madrid)

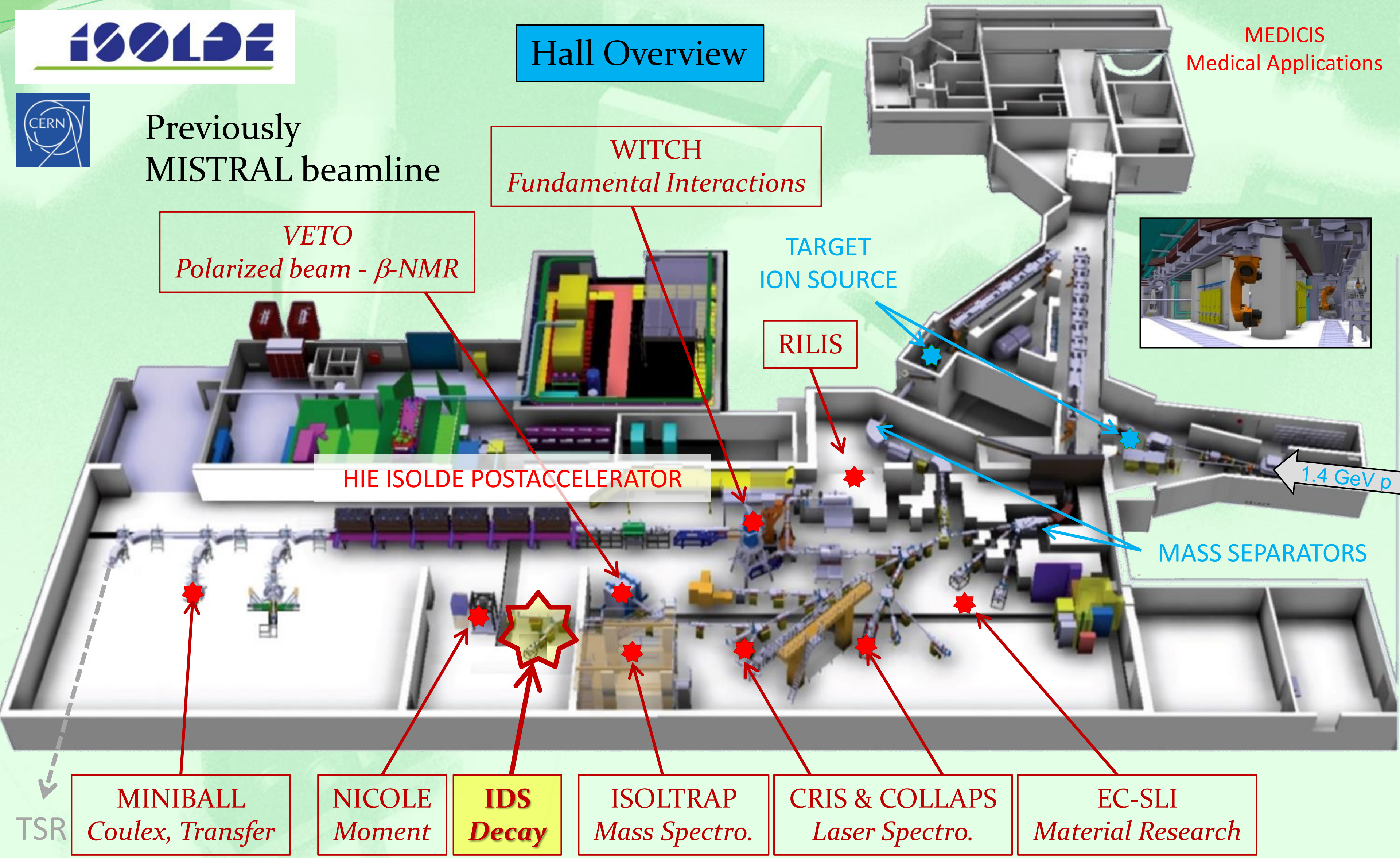
SWEDEN (Univ. of Lund)

SWITZERLAND (CERN - ISOLDE)

UK (STFC Daresbury Lab.; Univ. of Liverpool; Univ. of Manchester; Univ. of Surrey; Univ. of York)

PHASE 1 focused on β-decay studies

IDS setup at the ISOLDE Facility



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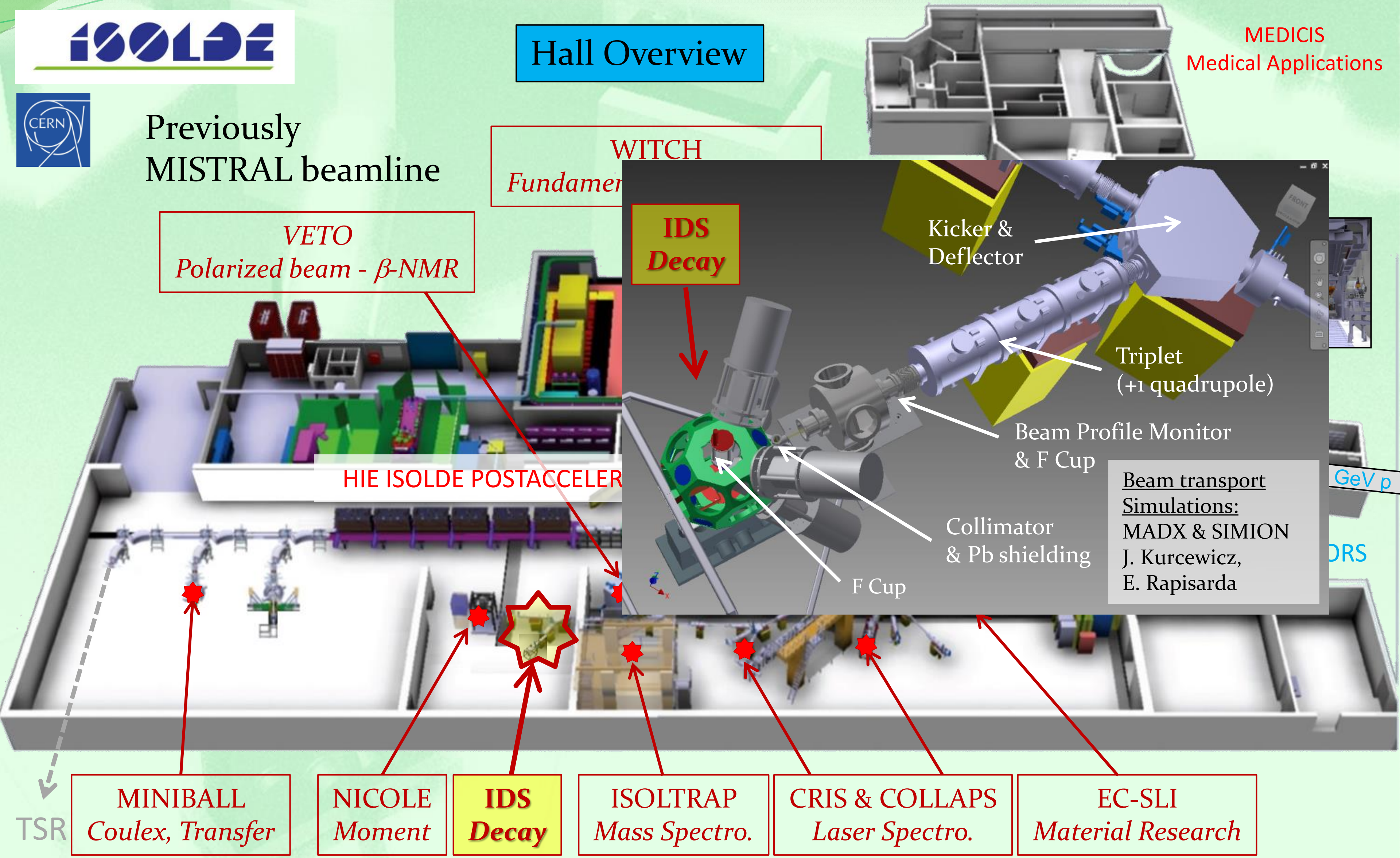
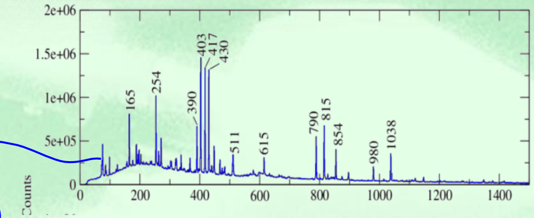
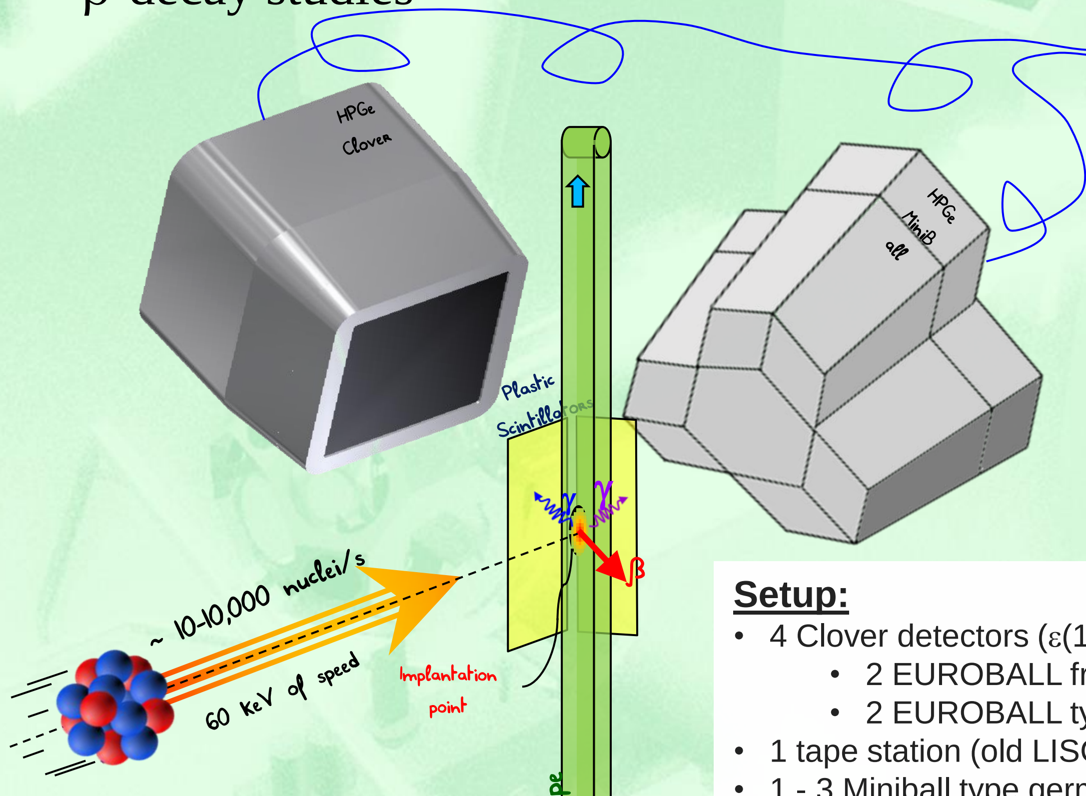


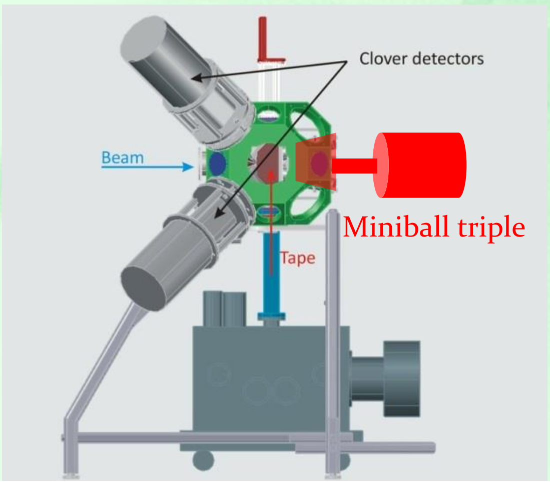
IDS setup at the ISOLDE Facility

- Standard Configuration(s):

β-decay studies







In order to study the shorter lived species :

detection point = collection point

(no motion of the source prior to measurement)

Setup:

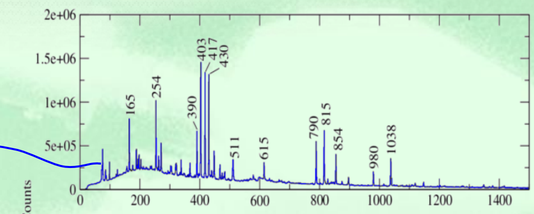
- 4 Clover detectors (ε(1MeV)~1.5% - FWHM 1.85-2.1 keV @1.3 MeV)
    - 2 EUROBALL from Bucharest
    - 2 EUROBALL type + Carbone Epoxy foil from Leuven
- 1 tape station (old LISOL setup) (cycle ~few 100 ms)
- 1 - 3 Miniball type germanium detector(s) from Leuven (22% Ω, ε(1MeV)~3%)
- 1 Low Energy Germanium detector (ISOLDE – under test)
- 3 Plastic detectors (ΔE , ~60% Ω) and/or 1 fast plastic detectors
- Frame from OSIRIS IFIN Bucharest

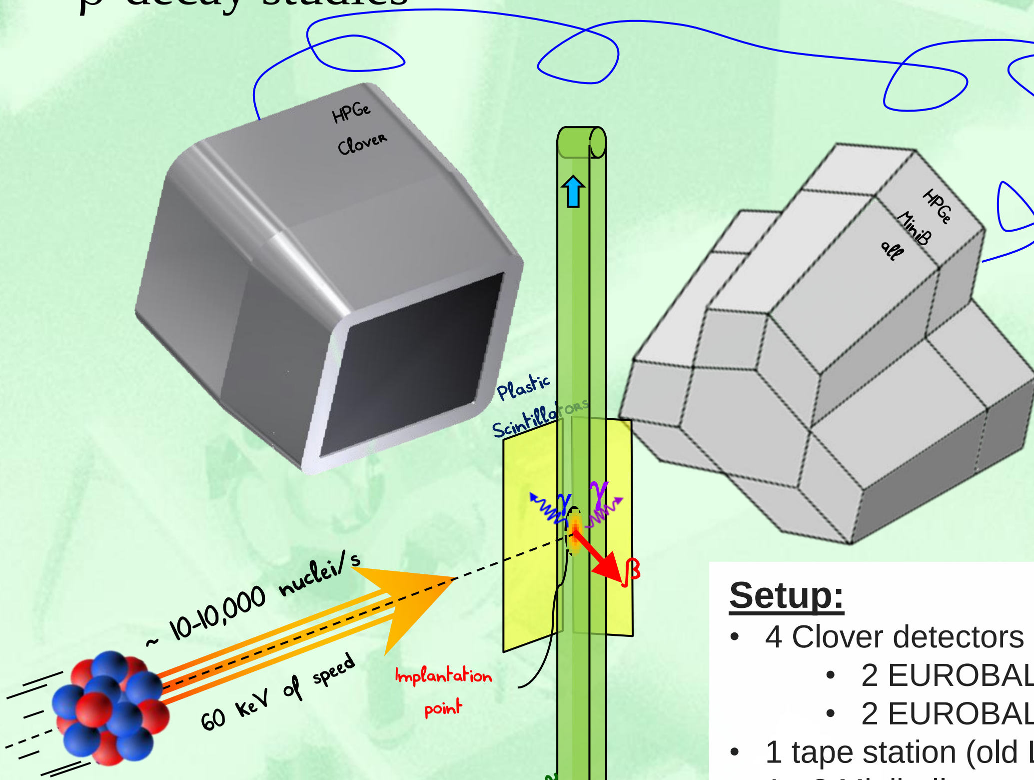
+ Ancillary detectors

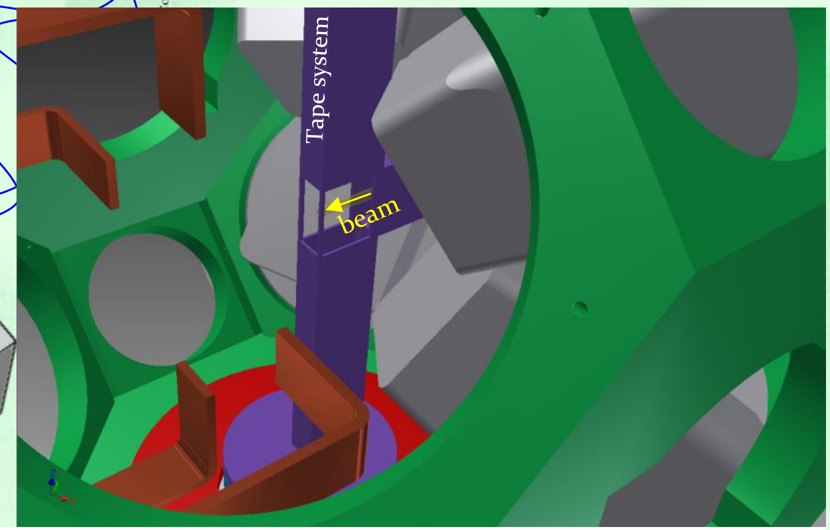
IDS setup at the ISOLDE Facility

- Standard Configuration(s):

β-decay studies







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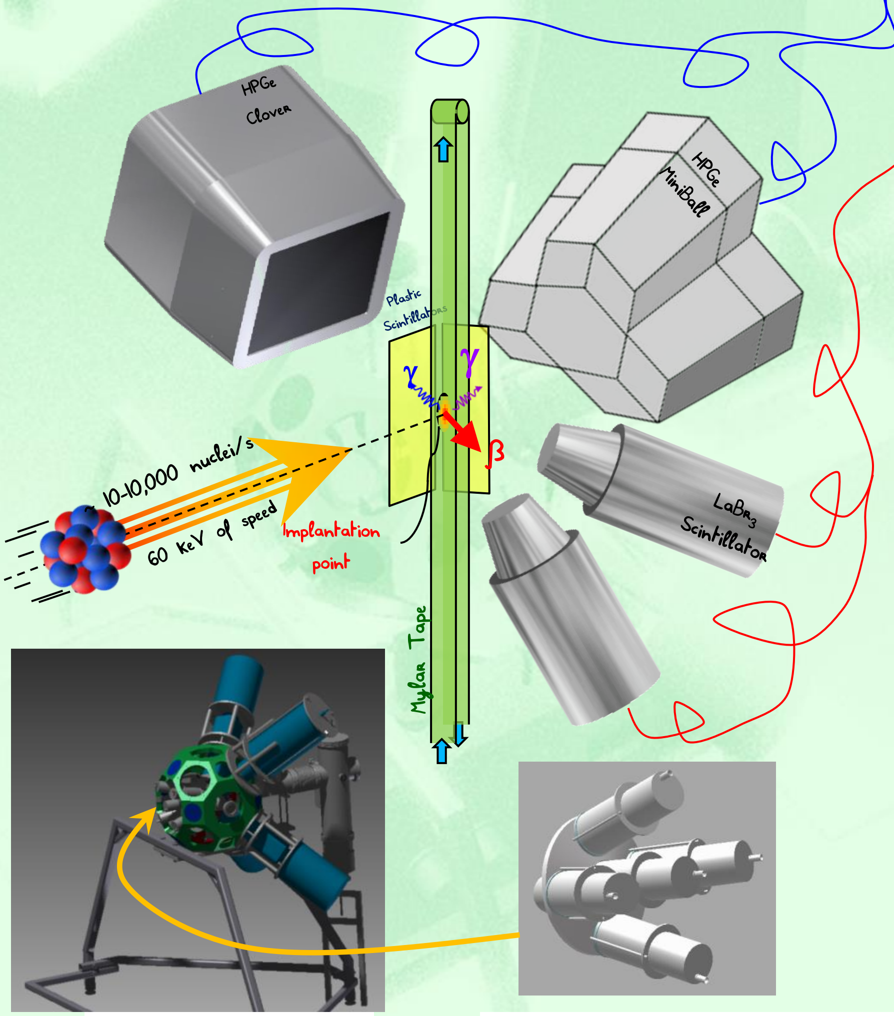
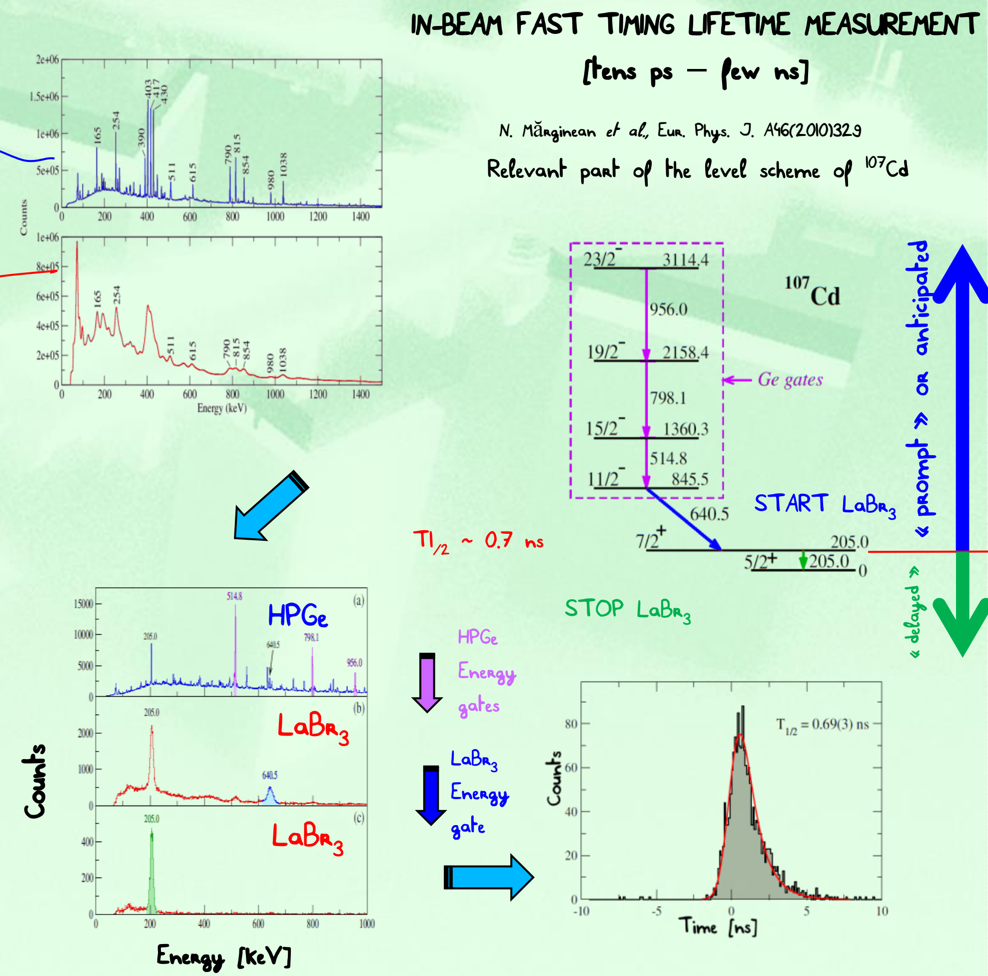
- Standard Configuration(s):

Fast Timing Technique





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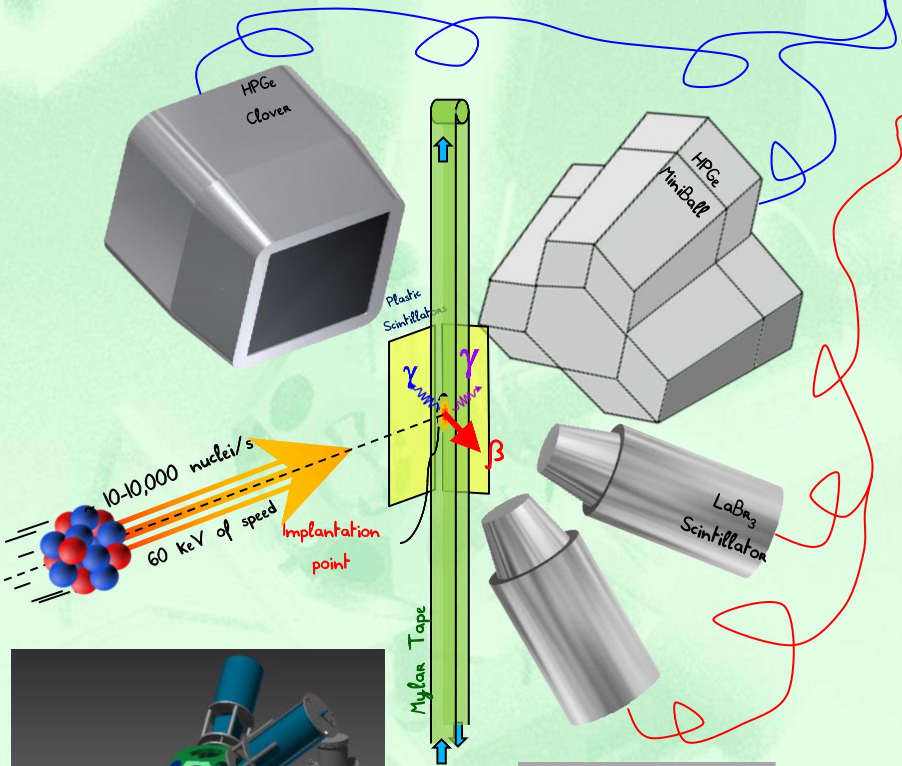
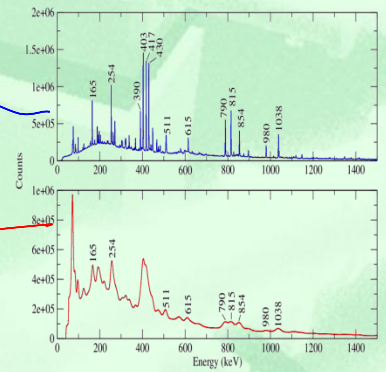
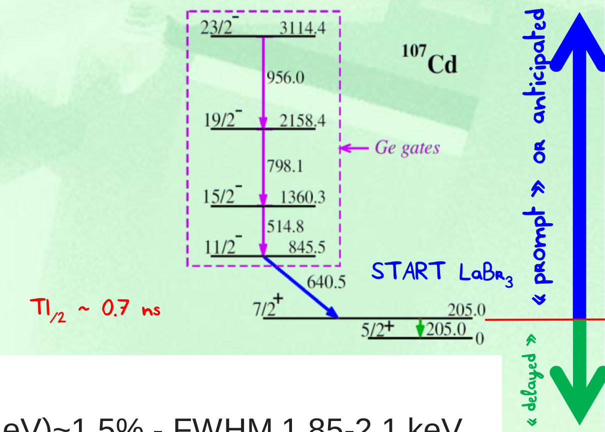


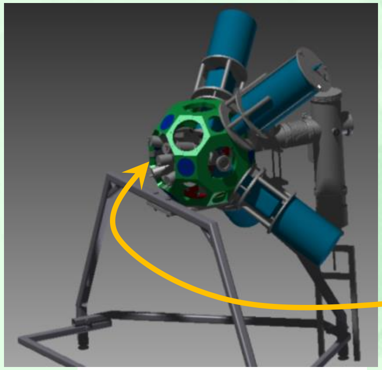


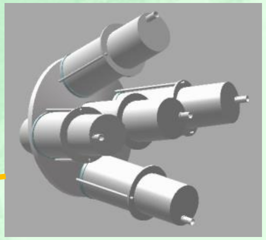
IN-BEAM FAST TIMING LIFETIME MEASUREMENT
[tens ps – few ns]

N. Mărginean et al., Eur. Phys. J. A46(2010)329

Relevant part of the level scheme of ^{107}Cd







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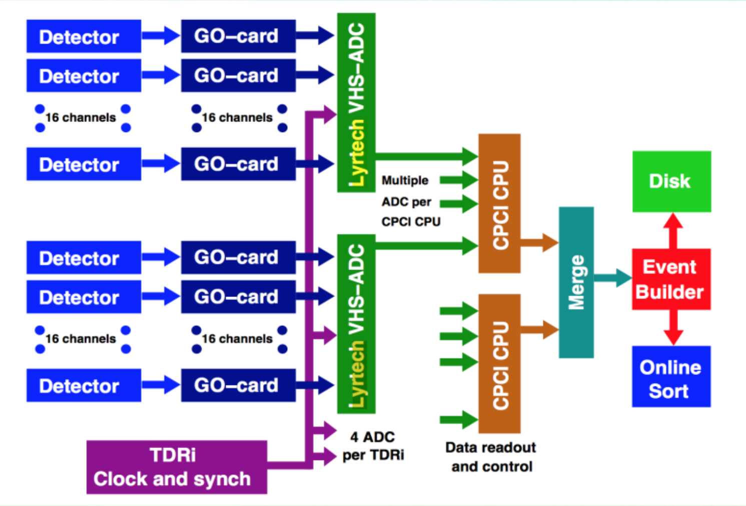
- 1 tape station (old LISOL setup) (cycle ~few 100 ms)
- **No Miniball**
- 1 Low Energy Germanium detector (ISOLDE – under test)
- **2 Plastic detectors**: (2 x ΔE, ~30% Ω)
- Frame from OSIRIS IFIN Bucharest

+ Ancillary detectors :

- **5 LaBr3** (~18-25% Ω)
- **1 fast plastic detectors** (1x E, ~30% Ω)

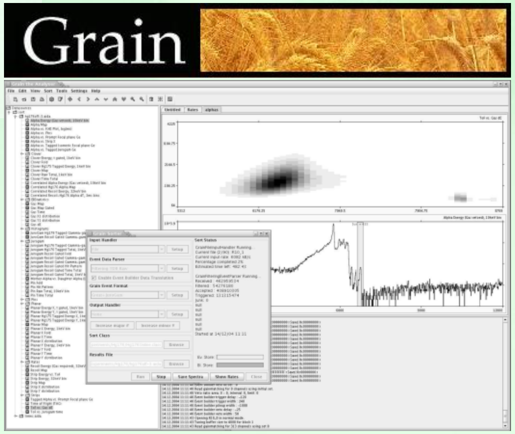
IDS setup at the ISOLDE Facility

- TDR - DAQ for IDS:
  - TDR – Total Data Readout (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 .
  - Event building and analysis has to be done entirely in the software post-processing the data stream.
  - VHS-ADC : 8 ch, 105 MSPS, 14-bit ADC (virtex4 FPGA) - could be available on loan from JYFL
  - Capable to handle rates ~30kHz/ch (DC beam)



- GRAIN – data analysis software:
  - GRAIN - data analysis framework 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, Grain - A Java Data Analysis System for Total Data Readout Nucl. Instr. and Meth. A 595, 637 (2008)

Lyrtech VHS-ADC

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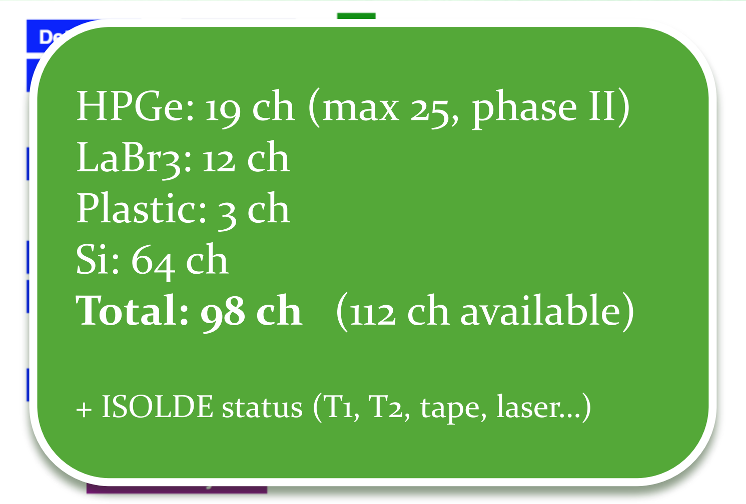

HPGe: 19 ch (max 25, phase II)
LaBr3: 12 ch
Plastic: 3 ch
Si: 64 ch
Total: 98 ch (112 ch available)

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

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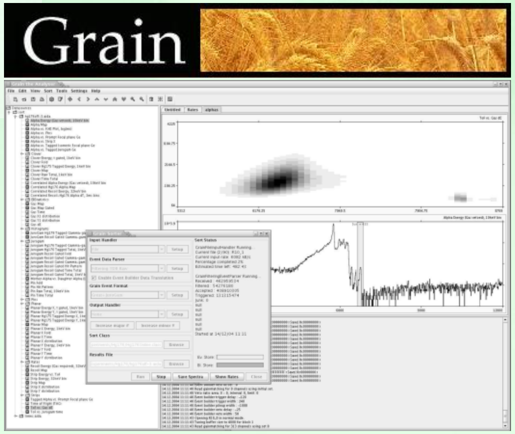


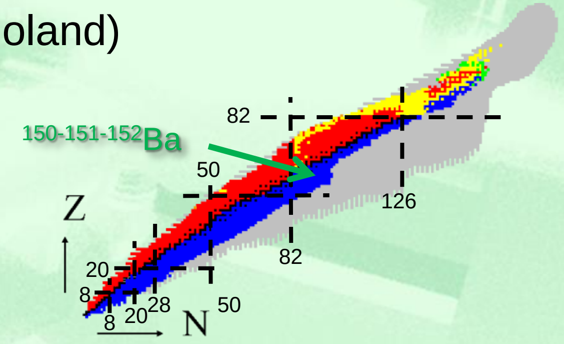
P. Rahkila, Grain - A Java Data Analysis System for Total Data Readout Nucl. Instr. and Meth. A 595, 637 (2008)

Lyrtech VHS-ADC

Approved IDS experiments

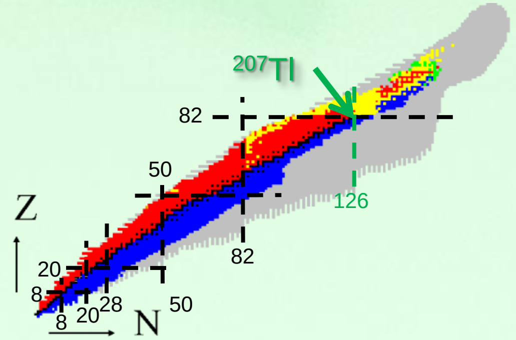
Study of octupole deformation in n-rich Ba isotopes populated via β-decay (IS579)

- Spokesperson: G. Benzoni (Univ. Milano), H. Mach (NCBJ, Poland)
- Physics:
  - $^{150\text{-}151\text{-}152}$Cs β-decay
  - Octupole deformations expected in the low-lying states
- Set-up and Methodology:
  - UCx target with standard surface ionizer
  - Fast plastic scintillator, 5 $LaBr_3(Ce)$ detectors and 4 HPGe Clover detectors
  - Fast timing, γ -γ coincidences



Core breaking and octupole low-spin states in ^{207}Tl (IS588)

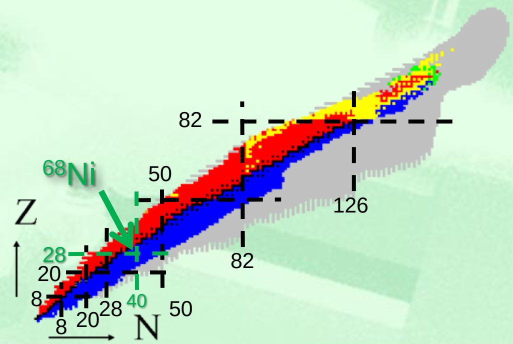
- Spokesperson: Zsolt Podolyák (Univ. Surrey)
- Physics:
  - Low-spin level structure of the ^{207}Tl by β-decay of ^{207}Hg
  - Breaking of the neutron or proton core
  - Collective octupole phonon coupled to the single proton hole
- Set-up and Methodology:
  - Molten Pb target
  - 4 HPGe Clover detectors + 1 MiniBall triple cluster + plastic scintillators
  - γ -γ coincidences



Approved IDS experiments

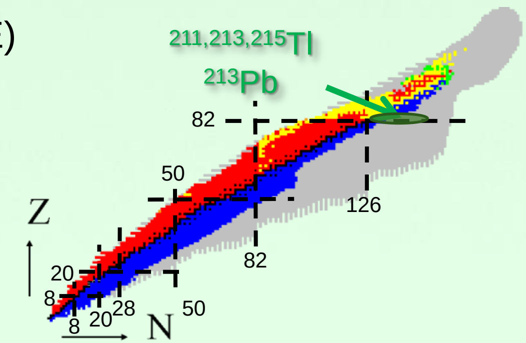
Characterization of the low-lying 0+ and 2+ states of ^{68}Ni (IS590)

- Spokesperson: C. Sotty (KU Leuven - IKS), L. Fraile (Univ. Madrid)
- Physics:
  - Detailed spectroscopic 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.
- Set-up and Methodology:
  - UCx target, neutron converter and RILIS
  - β-decay of ^{68}Mn-^{68}Fe-^{68}Co-^{68}Ni
  - Fast plastic detector, 5 $LaBr_3$(Ce) detectors and 4 HPGe Clover detectors
  - γ- and electron spectroscopy, fast timing



Beta-decay study of neutron-rich Tl and Pb isotopes (IS579)

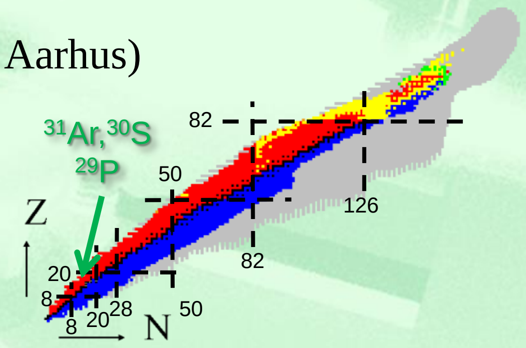
- Spokesperson: A. Gottardo (IPN Orsay), E. Rapisarda (CERN - ISOLDE)
- Physics:
  - Long-lived isomers in ^{211,213}Tl and β decay of $^{211-215}$Tl
  - Long-lived isomers in ^{213}Pb
- Set-up and Methodology:
  - UCx target using RILIS, quartz line - LIST
  - HPGe: 4 Clover detectors + 1 MiniBall triple cluster + plastic scintillators

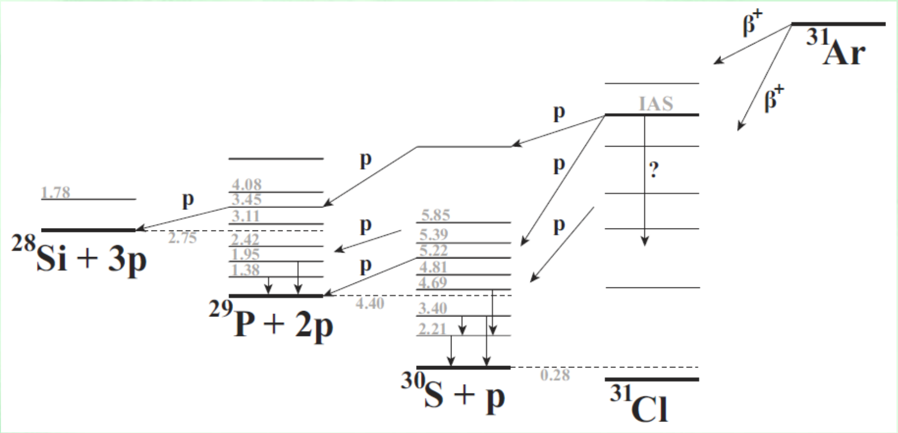


Approved IDS experiments

β3p spectroscopy and proton-γ width determination in the decay of ^{31}Ar (IS577)

- Spokesperson: H. O. U. Fynbo (Univ. Aarhus), G.T. Koldste (Univ. Aarhus)
- Physics:
  - Detailed study of the beta decay of the dripline nucleus ^{31}Ar.
  - Allow detailed study of the beta-delayed 3p-decay
  - Provide important information on ^{30}S and ^{29}P resonances





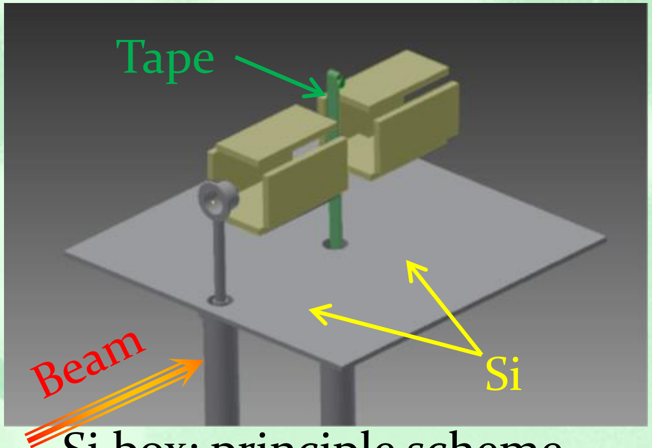
- Set-up and Methodology:
  - CaO target
  - Custom built chamber hosting an array of 6 DSSSD (70% Ω)
  - HPGe: 4 Clover detectors + 1 Miniball triple cluster

Outlooks and perpectives

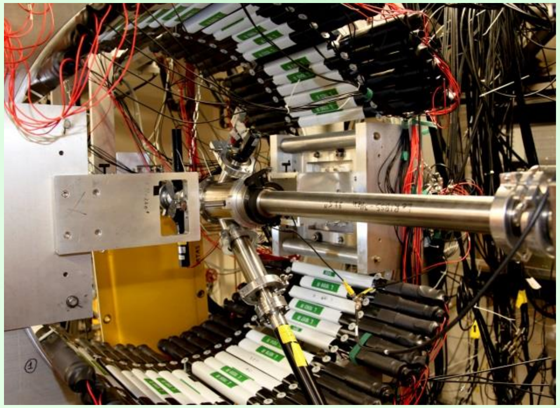
Different phases for different physics

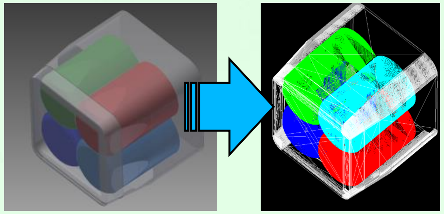
- **Phase 1 : (Current campaign 2014)**
  - Mainly beta-decay studies
  - Digital electronics (Nutaq system)
- **Phase 1.1 : (next campaign 2015)**
  - Electron Spectroscopy (Silicon box, design University of York)
  - Neutron spectroscopy (Coupling with VANDLE)

    Proposal of M. Madurga for next INTC
- **Phase 2 : (future)**
  - New frames and chambers
  - Possibly fast tape station
  - Possibly design of a new neutron detector (CERN)
- **Simulation package G4IDS:**
  - Based on *g4miniball*
  - CAD to Geant4 geometries
    - ➨ It works!
  - Normalization of photopeak efficiencies needed!!



Si box: principle scheme


VANDLE setup in ORNL


CAD to Geant4 Conversion

Contacts & Info

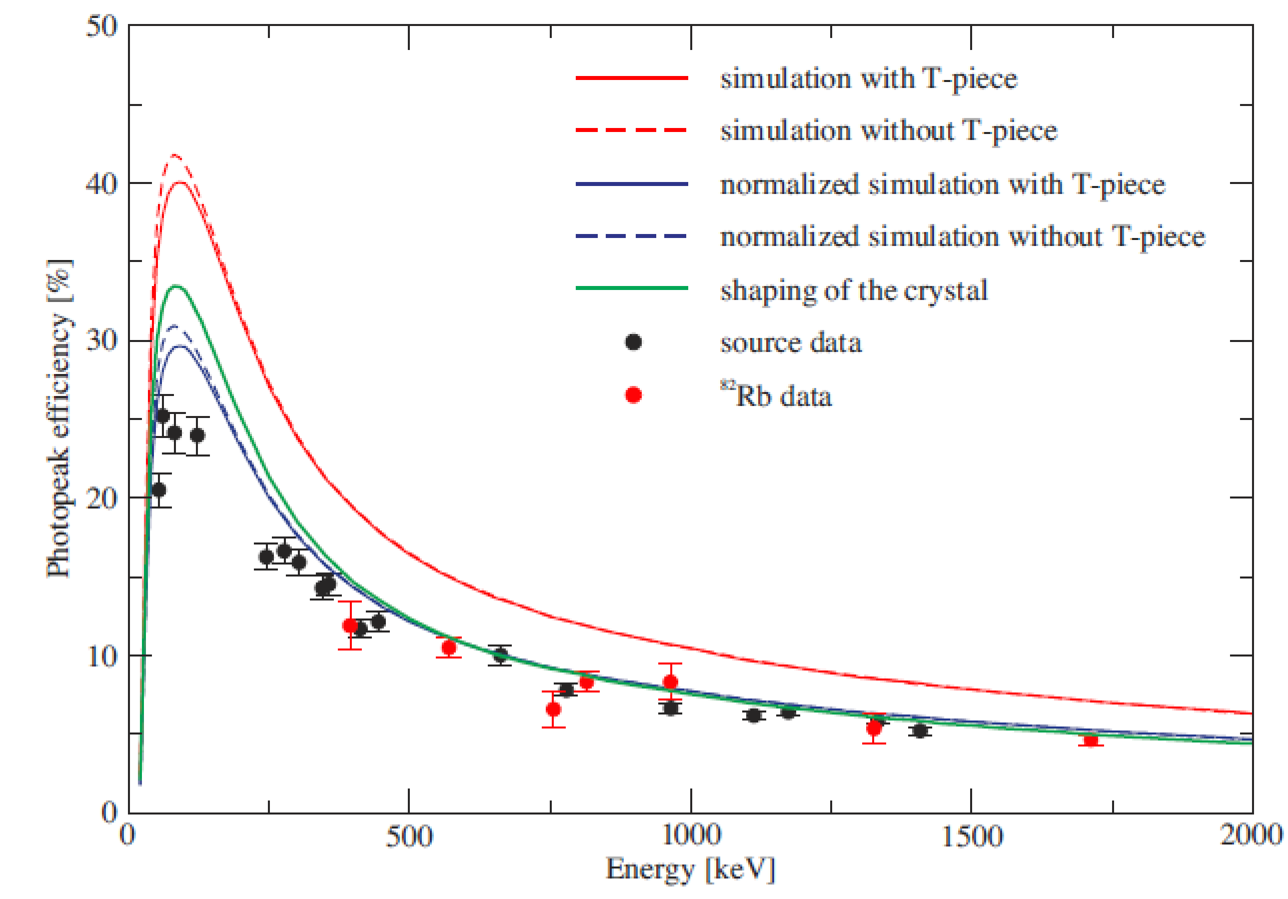
- **General Contact :**
  - Hilde De Witte
    KU Leuven - Nuclear and Radiation Physics Section
    Celestijnenlaan 200d - box 2418
    3001 Leuven Belgium
    Phone: +32 16 3 27270
    Email: *Hilde.dewitte@fys.kuleuven.be*
- **Local team :**
  - Sotty Christophe (*Christophe.Sotty@fys.kuleuven.be*)
  - Rapisarda Elisa (*Elisa.Rapisarda@cern.ch*)
  - Kurcewicz Jan (*Jan.Kurcewicz@cern.ch*)
  - Miguel Flores Madurga (*Miguel.Madurga@cern*.ch)
- **Geant4 Simulation:**
  - Sotty Christophe (*Christophe.Sotty@fys.kuleuven.be*)
- **Website :**

  Contact Hilde De Witte
  - *https://fys.kuleuven.be/iks/ns/ids*

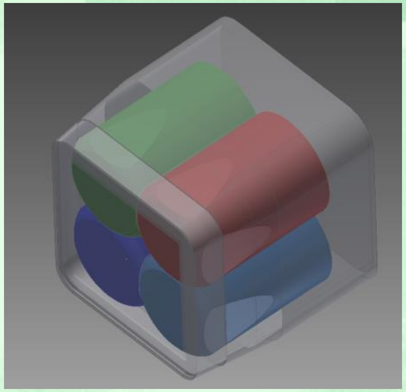
THANKS

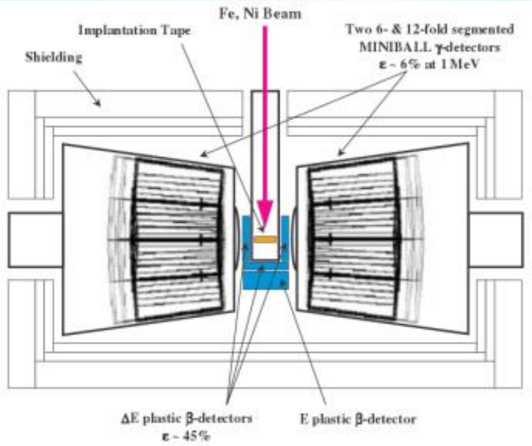
FOR YOUR ATTENTION

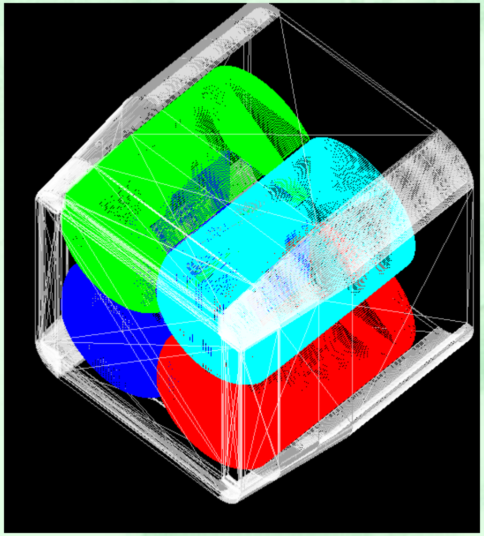
g4miniball Simulation

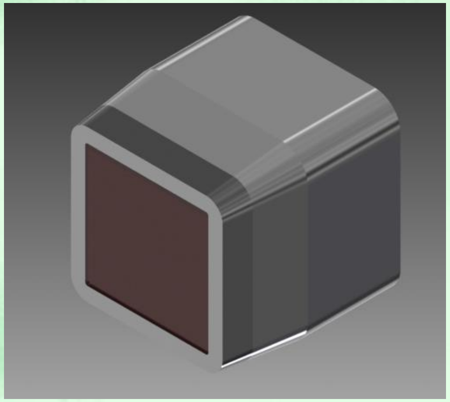


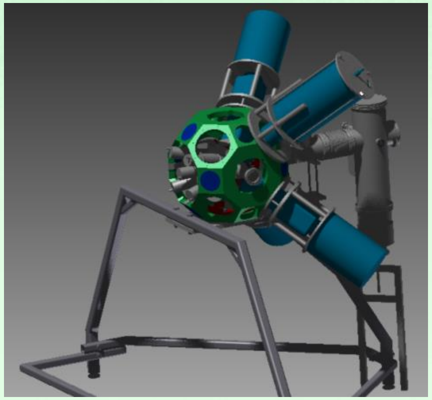
G4IDS Simulation

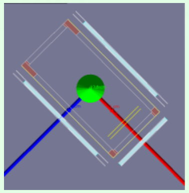












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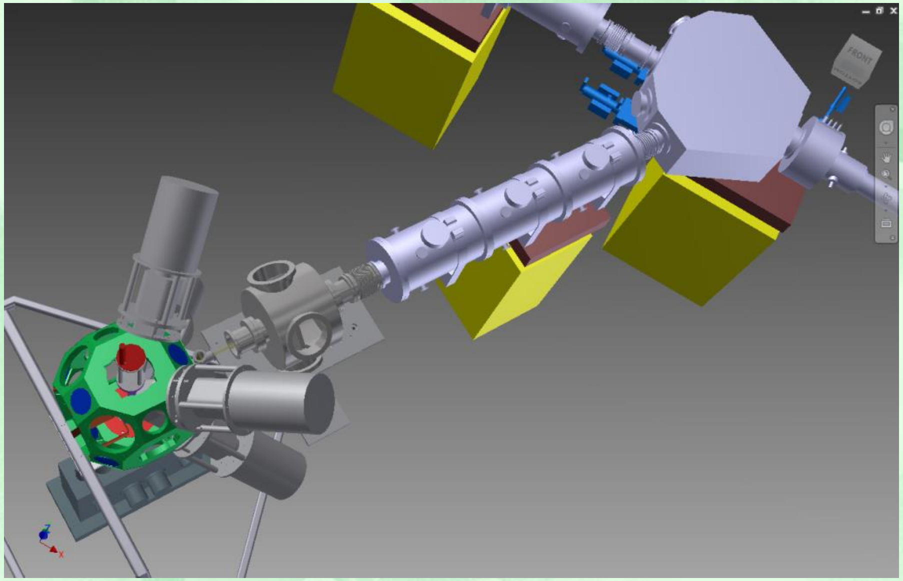
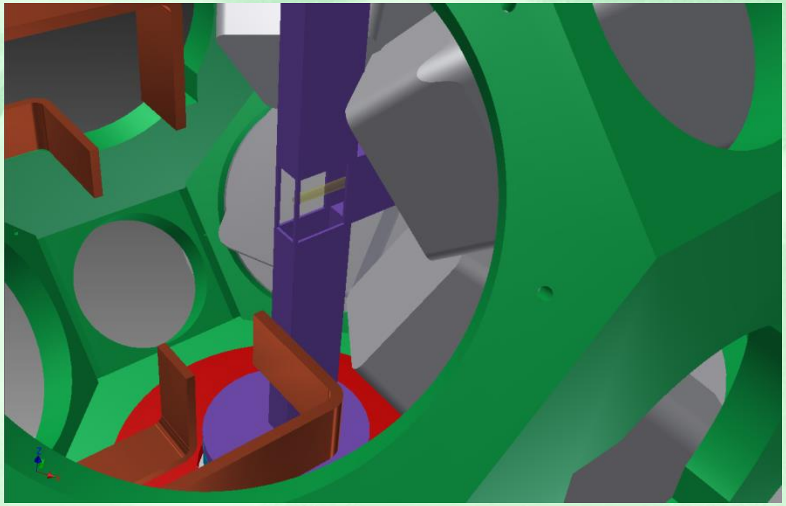
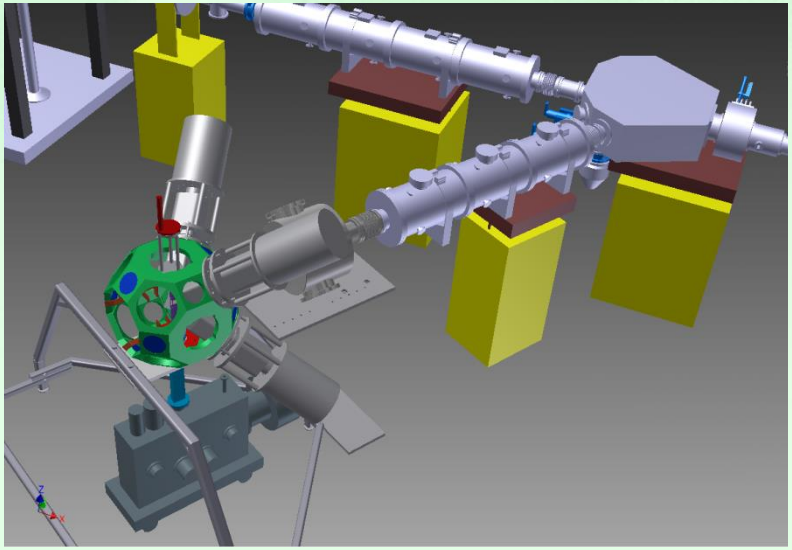


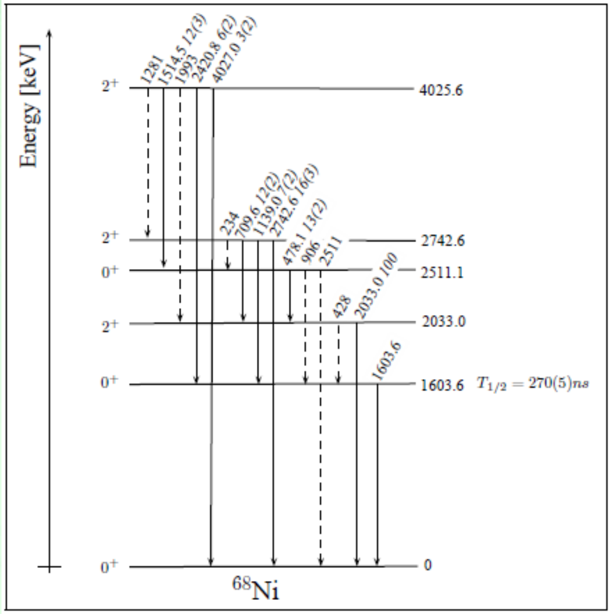


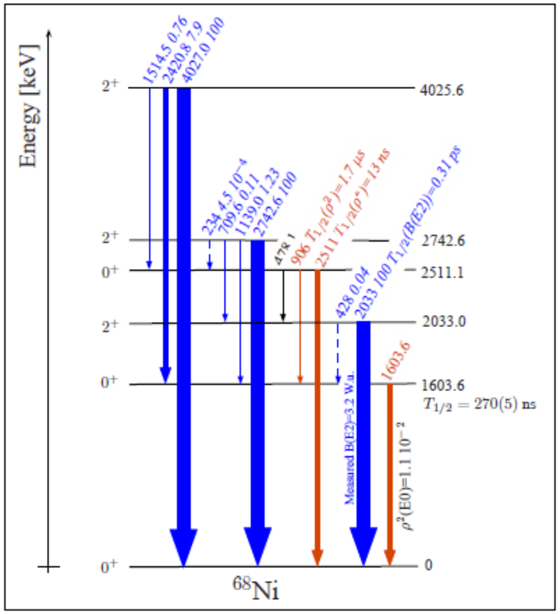


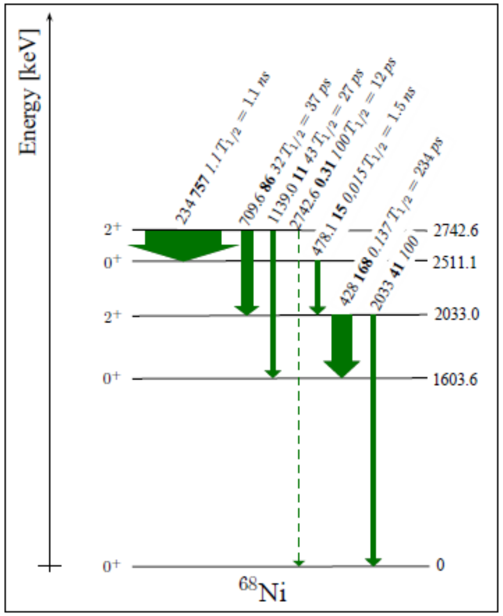
Characterization of the low-lying 0+ and 2+ states of 68Ni

Abstract:

Recently, a number of low-lying low-spin states have been firmly identified in ^{68}Ni; the position of the first excited state (which is a 0^+ state), the spin and parity of the second excited 0^+ state and the spin and parity of the second and third 2^+ states have been fixed. The identification of these three pairs of 0^+ and 2^+ states in ^{68}Ni (Z=28 and N=40) forms ideal tests to validate shell-model calculations and the effective interactions developed for the nickel region but also hints to triple shape coexistence including even strongly deformed structures. The aim of this proposal is to collect detailed spectroscopic data of the low-spin states of ^{68}Ni (Z=28, N=40) in order to characterize these triple pairs of 0^+ and 2^+ states. Gamma branching ratios of the 0^+ and 2^+ states and the E0 transition strengths as well as the E2 transition rate of the 0^+_3 will be obtained using the new ISOLDE Decay Station that is constructed from an efficient array of germanium detectors and further equipped with high resolution electron. The IDS germanium array will be supplemented with fast-timing detectors and high resolution electron detectors to determine the half-life of 0^+_3 states and the E0(0^+-0^+) decay branches. The low-spin states in ^{68}Ni will be populated in β decay of the low-spin isomer in ^{68}Co($T_{1/2}$=1.6 s), which will be produced by the decay of ^{68}Mn laser-ionized by RILIS.







Study of octupole deformation in n-rich Ba isotopes populated via beta-decay

Abstract: We propose to exploit the unique capability of the ISOLDE facility to produce $^{150-151-152}$Cs beams to investigate their radioactive β-decay to $^{150-151-152}$Ba. The interest to study this mass region is twofold: from one side these nuclei are expected to show octupole deformations already in their low-lying state, and, on the other hand, gross information on the β decay is highly demanded for nuclear astrophysical model, given the fact that the r-process path lies in the proximity of accessible nuclei. The experiment will be performed with the ISOLDE Decay Station (IDS) setup using the fast tape station of K.U.-Leuven, equipped with 4 Clover Germanium detectors, 4 $LaBr_3$(Ce) detectors and 1 LEP HPGe detector. Information on the β decay, such as lifetimes and delayed neutron-emission probabilities, will be extracted, together with the detailed spectroscopy of the daughter nuclei, via $\gamma - \gamma$ coincidences and lifetimes measurement of specific states.

Strong octupole correlations appear when the Fermi level lies between the subshell of normal parity and an intruder orbital with angular momentum which differs by three units, $\Delta J = \Delta I = 3$. This condition is fulfilled for proton numbers Z= 34, 56 and 88, or for neutron numbers N= 34, 56, 88 and 134.

The experimental observables providing information on the nuclear shape are electric moments of excited states and electromagnetic transition rates between them. In particular, strong octupole correlations leading to reflection asymmetric shapes are characterized by phenomena such as interleaved positive- and negative-parity rotational bands, in even-even nuclei, or parity doublets, in odd-A nuclei, giving rise to enhanced electric dipole (E1) and octupole (E3) transitions that connect rotational states of opposite parity. In case of stable octupole-deformed nuclei, the electric-dipole strength is expected to remain constant at increasing values of the angular momentum. The appearance of alternating-parity bands is due to quantum interference between the two degenerate intrinsic states characterized by the same value of the octupole momentum but with different sign (in a pictorial way the pear-shaped distributions point in different directions). These levels are connected by E1 transitions with large B(E1) values. However this regular pattern seem to appear only at medium spin values (I>5), and it is usually lost at high values of spin. This is confirmed by the non-appearance of backbending phenomena at increasing spin values, and it is a consequence of the stabilizing effect of octupole deformation on angular momentum, given the larger moment of inertia of octupolar shapes.

Characterization of the low-lying 0+ and 2+ states of 68Ni

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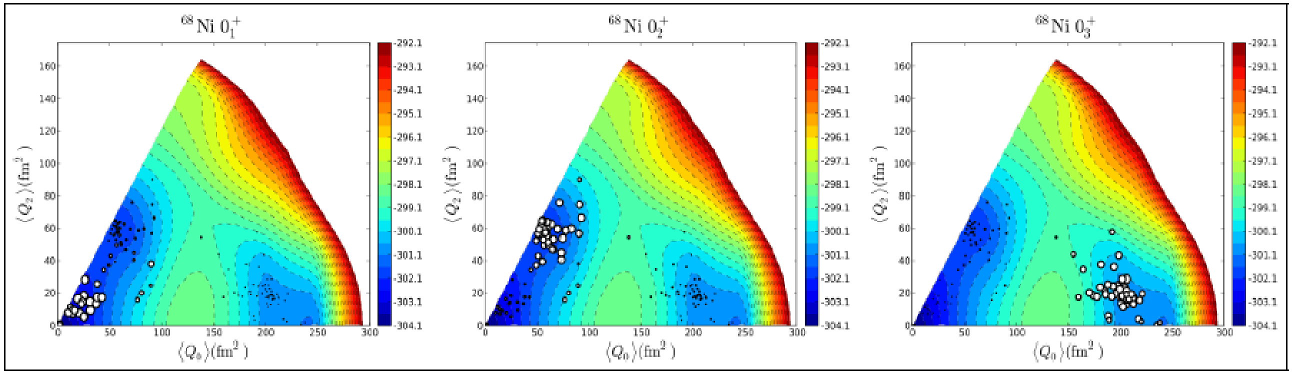


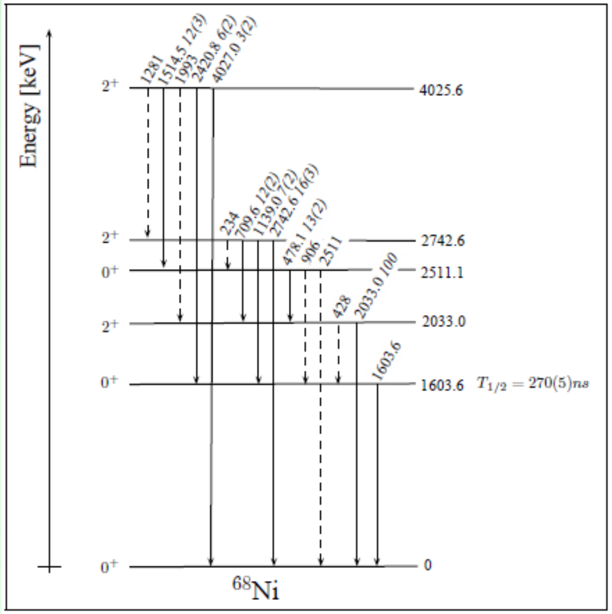
Figure 1: Total energy surface of the 0_1^+ (left), 0_2^+ (middle) and 0_3^+ (right) states of ^{68}Ni. The positions of the red circles represent quadrupole deformations of the MCSM basis states before projection. The areas of those circles represent the overlap probabilities of the basis states and the resulting wave function. Based on Ref. [13].

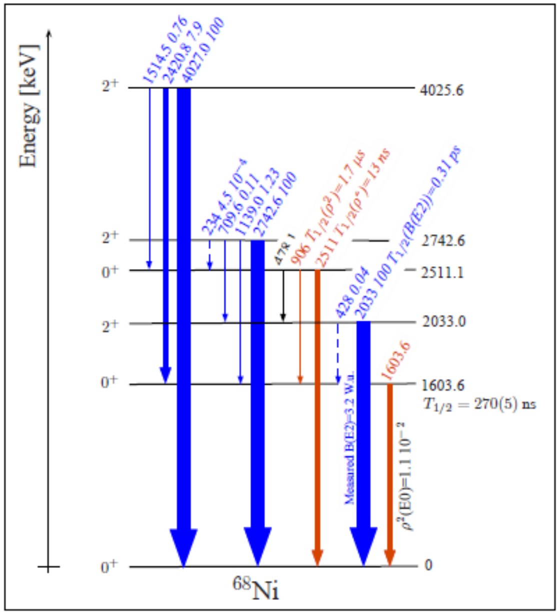
[13] Y. Tsunoda, T. Otsuka, N. Shimizu, M. Honma, and Y. Utsuno, Journal of Physics: Conference Series **445**, 012028 (2013).

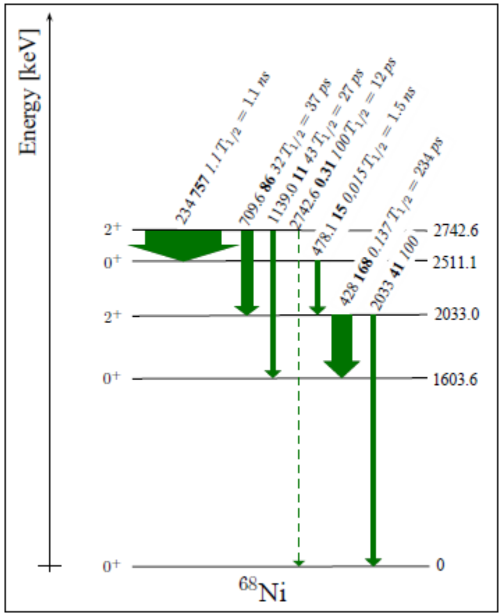
Characterization of the low-lying 0+ and 2+ states of 68Ni

- 2511 keV state, ~1.5ns or longer
- γ_{LaBr3} (478)-γ_{LaBr3}(1515) not sufficient (due to $\varepsilon_{LaBr3-LaBr3}$ too low)
- But β-γ_{LaBr3} coinc. are sufficient
- Possible cleaning with the HPGe but lower statistics

- 0_3^+->0_1^+ : 1400 Cts in the beta-gated electron 745keV-511keV gamma gate
- But the intensity will depend and the B(E2;478keV) and ρ^2(E0) strength
- 0_3^+->0_1^+: 906-keV transition ~48Cts







Core breaking and octupole low-spin states in 207Tl

Abstract

We propose to study the low-spin level structure of the ^{207}Tl nucleus populated by the beta decay of ^{207}Hg. While ^{207}Tl is a single-proton hole nucleus, the majority of the observed states will have three-particle structure thus requiring the breaking of the neutron or proton core, or a collective octupole phonon coupled to the single proton hole. Thus information will be obtained on the single particle orbitals in the vicinity of the N=126 and Z=82 magic numbers, and on the size of the shell gap.

The results will be used to improve the predictive power of the shell model for more exotic nuclei as we move to lighter N=126 nuclei.The experiment will use the ISOLDE Decay station, and will take advantage of the ^{207}Hg beam from the molten lead target. A test on the feasibility to produce ^{208}Hg beam from the same target, with the aim to study the beta-decay into ^{208}Tl, could be performed at the same time.

Beta-decay of neutron-rich Tl and Pb isotopes

Abstract

It is proposed to study the structure of neutron-rich nuclei beyond ^{208}Pb. The one-proton hole $^{211-215}$Tl and the semi magic ^{213}Pb will be produced and studied via nuclear and atomic spectroscopy searching for long-lived isomers and investigating the beta-delayed gamma emission to build level schemes. Information on the single particle structure in $^{211-215}$Pb, especially the position of the $g_{9/2}$ and $i_{11/2}$ neutron orbitals, will be extracted along with lifetimes. The beta-decay will be complemented with the higher spin selectivity that can be obtained by resonant laser ionization to single-out the decay properties of long-living isomers in ^{211,213}Tl and ^{213}Pb.

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

Abstract: We propose to perform a detailed study of the β-decay of the dripline nucleus ^{31}Ar. This will allow a detailed study of the β-delayed 3p-decay as well as provide important information on the resonances of ^{30}S and ^{29}P, in particular the ratio between the proton and γ partial widths relevant for astrophysics.

β2p decay mode 16 years ago. The goal of identifying non-sequential decay modes both in β2p and β3p remains and will be pursued also in the new experiment with increased sensitivity. Finally, a new measurement will provide a much better measure of the β-strength distribution both in the Fermi and Gamow-Teller part in particular with the better measurement of the β2p and β3p branches to high lying states, which represent relatively large β-strength per decay. These points will be discussed in more detail below.

IDS - PHASE 1

IDS

ISOLDE **D**ECAY **S**TATION

- Beta/Gamma-ray spectroscopy following β-decay
- Fast timing
- Electron spectroscopy for phase 1.1