

Five Years of Applications of EXOCTIC radioactive ion beams at ISOLDE

new tools, new ideas, new people



João Guilherme Correia

IST-ITN

Instituto Técnológico e Nuclear - Instituto Superior Técnico
Universidade Técnica de Lisboa, Portugal
and
ISOLDE-CERN, Switzerland



“APPLICATIONS” OF EXOTIC RADIOACTIVE BEAMS

Presenting a review of today's offer...

- What is working and is new ...
- What is useful and ... usable
- Who are the users ...
- Where ...

... aiming to work better in 10 – 15 years !

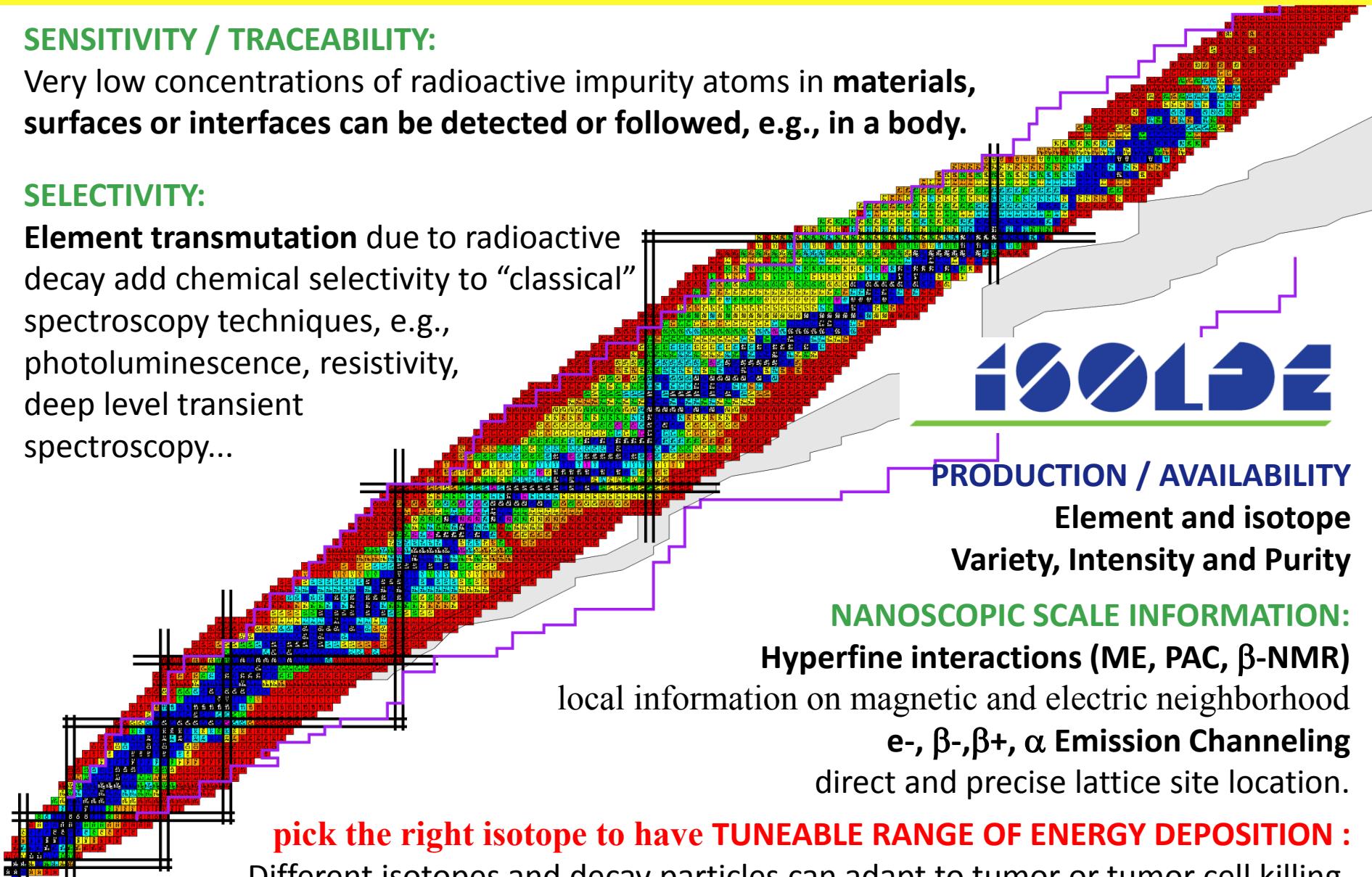
KEY Features for Sustainability of RIB Applications

SENSITIVITY / TRACEABILITY:

Very low concentrations of radioactive impurity atoms in **materials, surfaces or interfaces can be detected or followed, e.g., in a body.**

SELECTIVITY:

Element transmutation due to radioactive decay add chemical selectivity to "classical" spectroscopy techniques, e.g., photoluminescence, resistivity, deep level transient spectroscopy...



isotope

PRODUCTION / AVAILABILITY

Element and isotope Variety, Intensity and Purity

NANOSCOPIC SCALE INFORMATION:

Hyperfine interactions (ME, PAC, β -NMR)

local information on magnetic and electric neighborhood

e^- , β^- , β^+ , α Emission Channeling

direct and precise lattice site location.

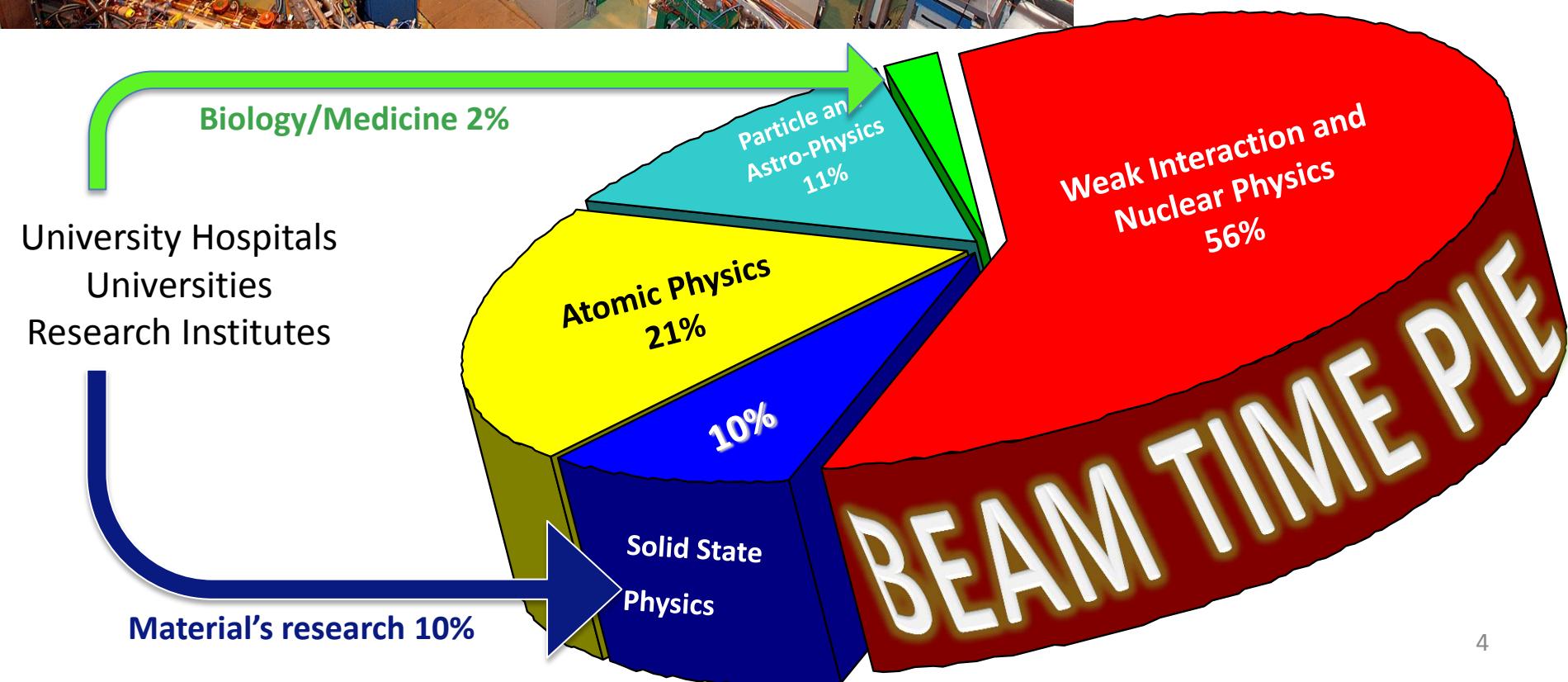
pick the right isotope to have TUNEABLE RANGE OF ENERGY DEPOSITION :

Different isotopes and decay particles can adapt to tumor or tumor cell killing.



2011

37 Experiments
300 Users
96 Institutes
22 Countries
235 8h-shifts of radioactive beams



SSP + BIO @ ISOLDE: Diverse community



1 32

Running experiments/letters of intent	24
Participating countries	26
Scientists	160

Current and PROSPECTIVE Work using EXOTIC Radioactive isotopes

→ THINKING Materials and Molecular Properties ←

dealing with mass, electromagnetism, many body systems and scaling
Atomic-like information is the aim !

→ Semiconductor Physics (Si, Oxides, organic compounds)

→ Multi- ferroic- magnetic, Superconductors (correlated parameters}

→ Nanomaterials (geometry, downsizing and integration)

→ Surfaces and interfaces (bulk properties are modified)

→ Soft matter : liquid crystals and graphen,

→ Bio / Molecular chemistry and physics

→ THINKING Life Sciences ←

optimizing delivering and range of deposition of highly concentration of energy upon radioactive decay into the living body or cell of interest.

Enlarging the choices of radioisotopes is the aim !

→ NEW isotopes and decay modes for diagnosis and treatments.

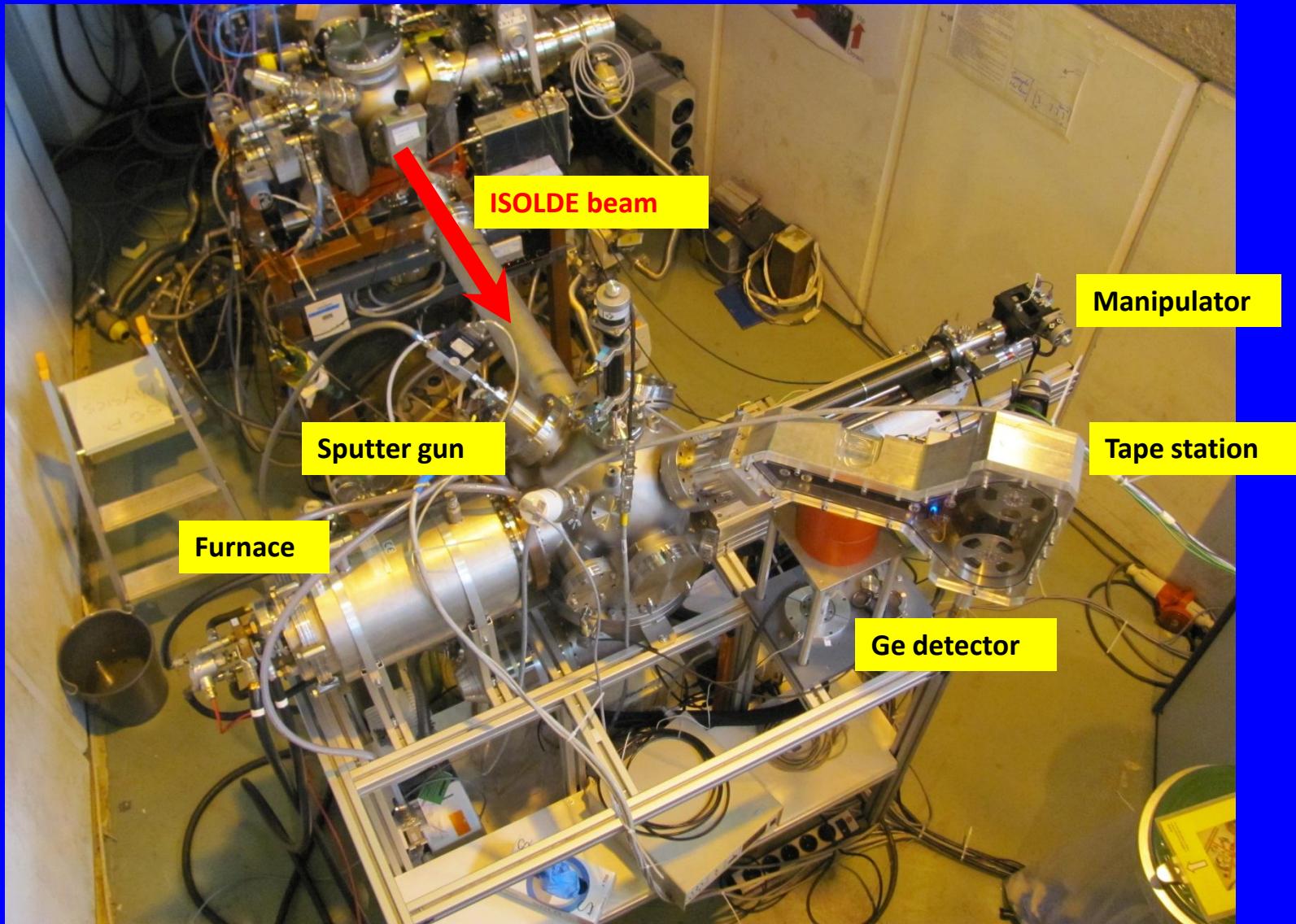
RECENT DEVELOPMENTS

A commitment for the future based on facts !



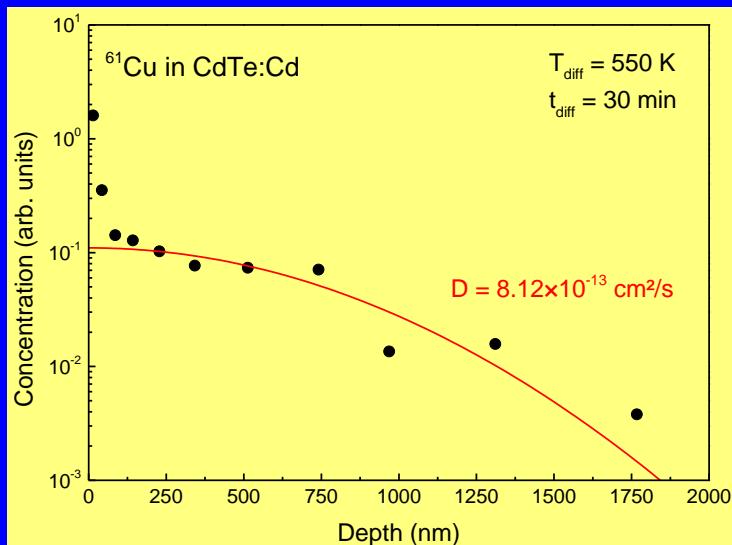
On-line diffusion chamber at ISOLDE

2011



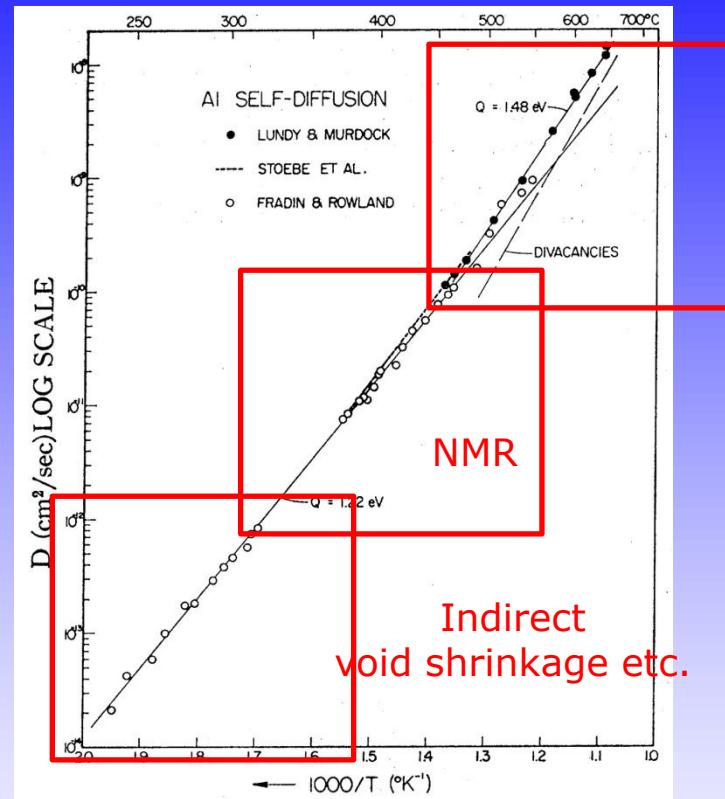
Understanding Diffusion and self diffusion ... On-line !

^{61}Cu (3.3h) diffusion in Cd saturated CdTe



Isotope	$t_{1/2}$	Detection
^{38}Cl	37.3 min	β^- 4800keV ; γ 2168keV
^{11}C	20.38 min	β^+ ; γ 511keV
^{13}N	9.96 min	β^+ ; γ 511keV
^{29}Al	6.6 min	γ 1273keV
(^{15}O)	122 s	β^+ ; γ 511keV

Unknown Aluminum self diffusion



(T.G.Stoebe *et al.*, Phys. Rev. 166 (1968) 621)

- ◆ Single stable Al isotope: no SIMS measurements
- ◆ Unknown activation energy of self diffusion in Al
- ◆ Unknown role of vacancies, di-vacancies at different temperatures.
- ◆ Unknown Al diffusion in Al-based compounds

From the Avogadro Project : define Kg in terms of number of Si atoms...

$$N_A = \frac{V_{\text{mol}}}{V_o}.$$

$$N_A = \frac{V_{\text{mol}}}{(a^3/n)},$$

$$N_A = \frac{M_{\text{Si}}}{m} \frac{V}{(a^3/8)},$$

Scientific American
295, 102 – 109 (2006)



PL + L-DLTS apparatus at ISOLDE



LASER

- HeCd (3,8 eV)
- Nd:YAG (2,3 nm)
- Diode (1,9 nm)

Cryostat

He-Bathcryostat (1,5 – 300 K) Closed cycle

Monochromator

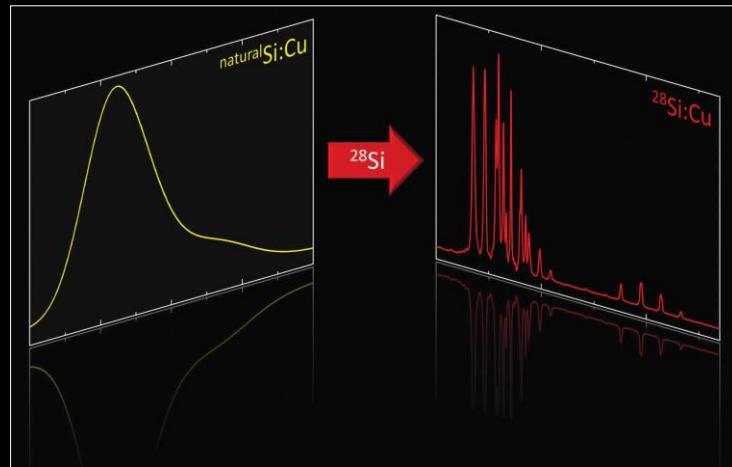
- Focus: 0,75 m
- Gratings: 150 – 1800 l/mm

Detectors

- CCD-camera (1,1 - 6,2 eV)
- Ge-Diode (0,7 - 1,5 eV)

... to measure optical properties of mono-isotopic Si.

JOURNAL OF APPLIED PHYSICS

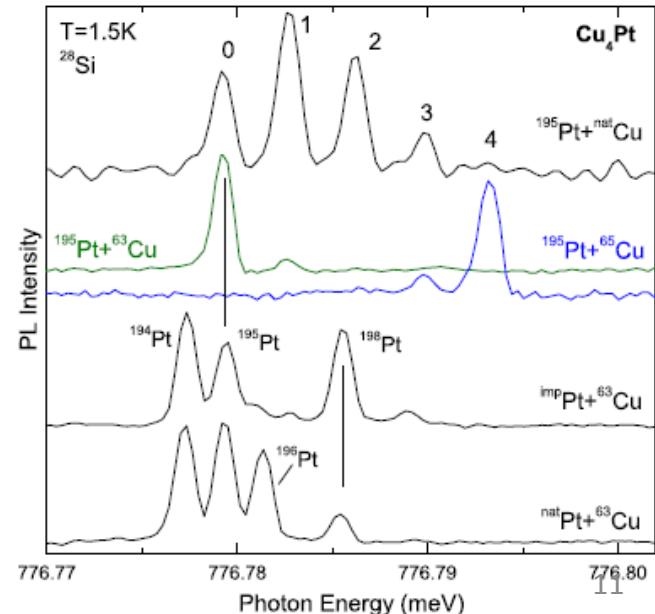


*Photoluminescence of deep defects involving transition metals in Si:
New insights from highly enriched ²⁸Si
by M. Steger, A. Yang, T. Sekiguchi et al.*

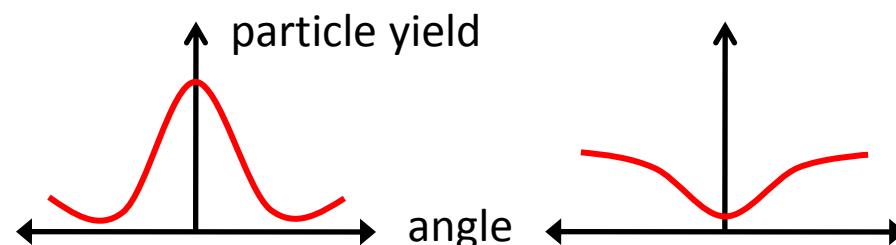
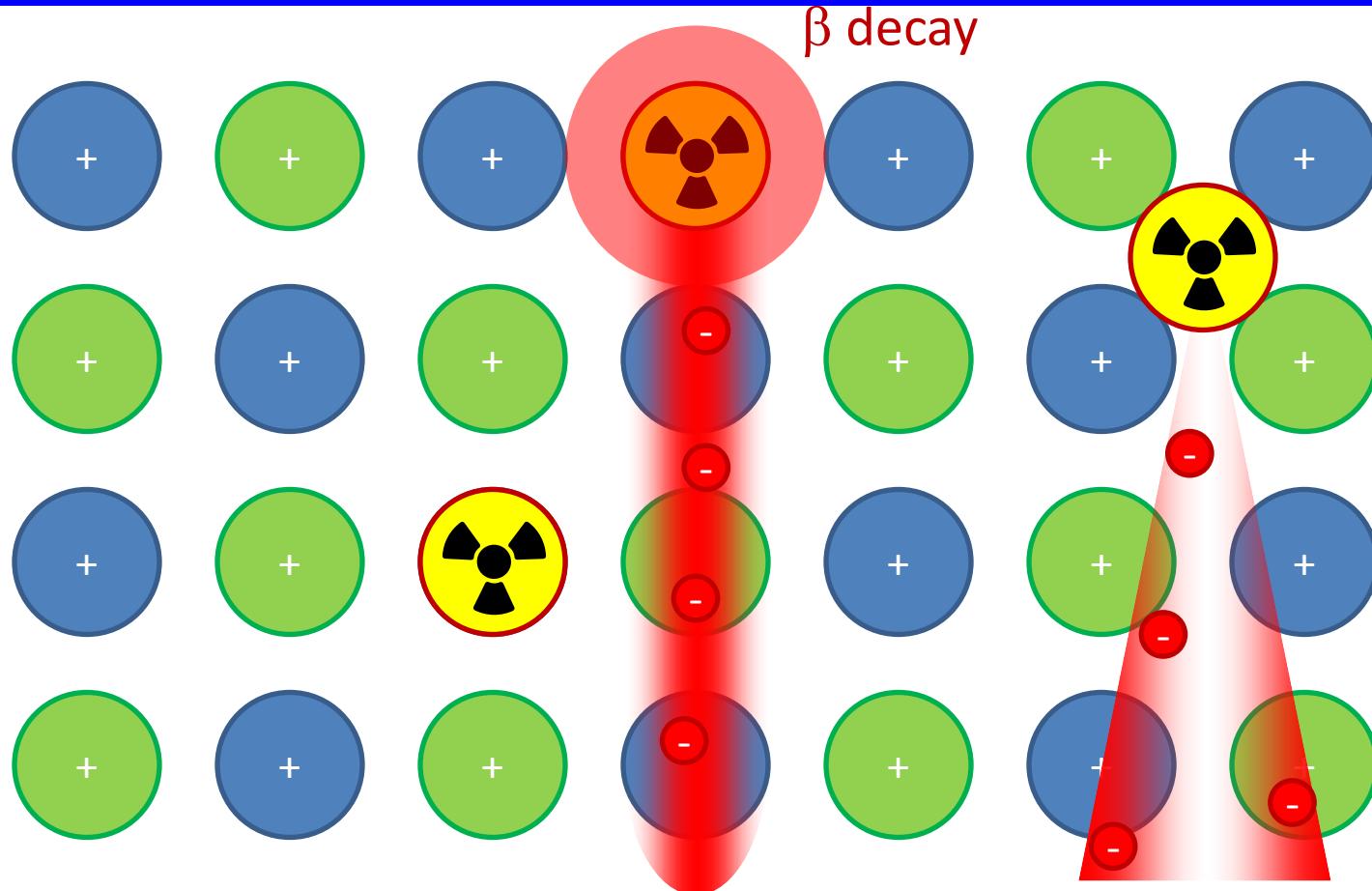
AIP

Hg195 9.9 h 1/2- EC	Hg196 0+ * 0.15	Hg197 64.14 h 1/2- EC	Hg198 0+ * 9.97
Au194 38.02 h 1- EC	Au195 186.09 d 3/2+ EC	Au196 6.183 d 2- EC β^-	Au197 3/2+ * 100
Pt193 50 y 1/2- EC	Pt194 0+ * 32.9	Pt195 1/2- * 33.8	Pt196 0+ * 25.3

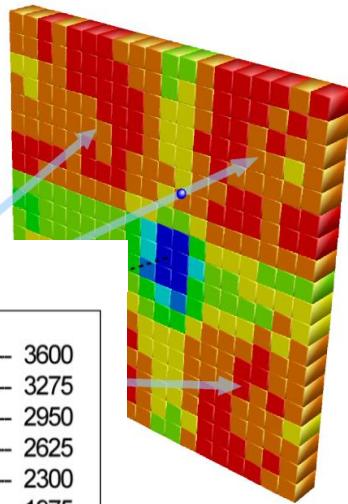
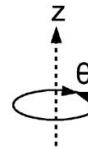
777meV feature, now shown to
include Pt and 4 Cu atoms!



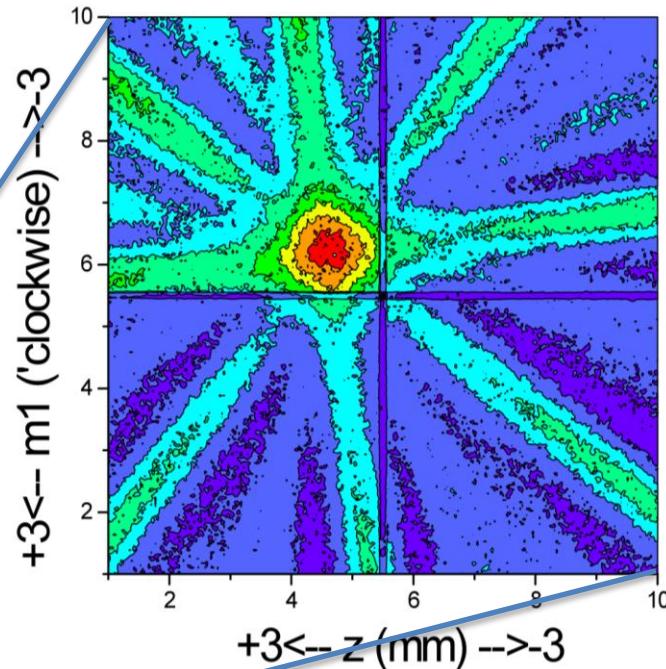
Emission Channeling of decay particles, on single crystals $(\beta^-$, β^+ , c.e., α)



2012



β^- from $^{89}\text{Sr}(50\text{d}) \text{ SrTiO}_3 <100>$



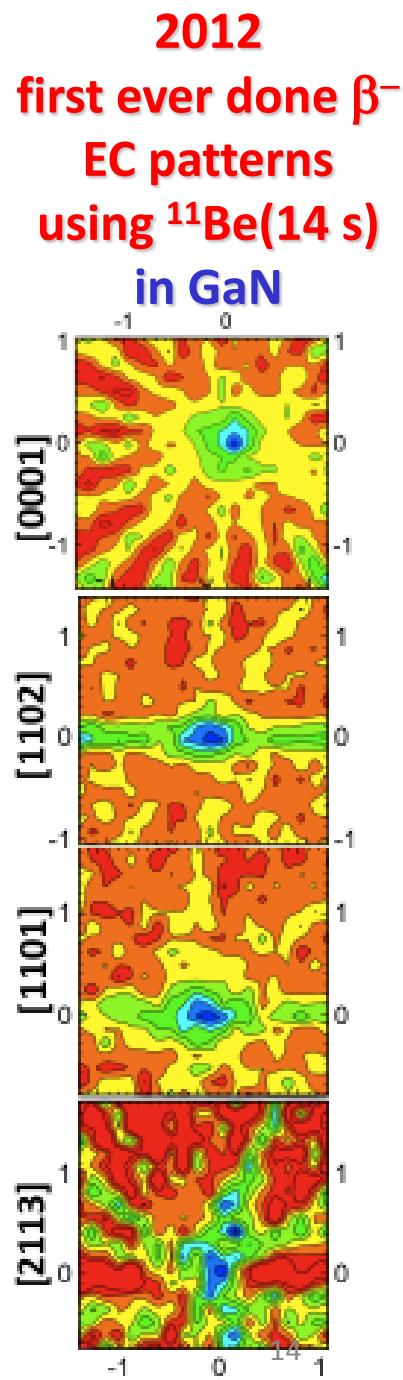
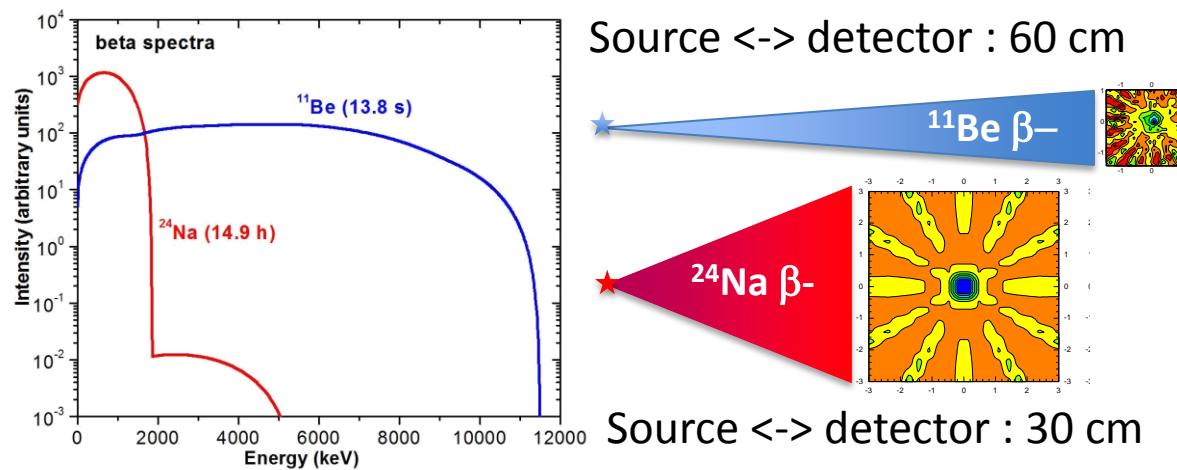
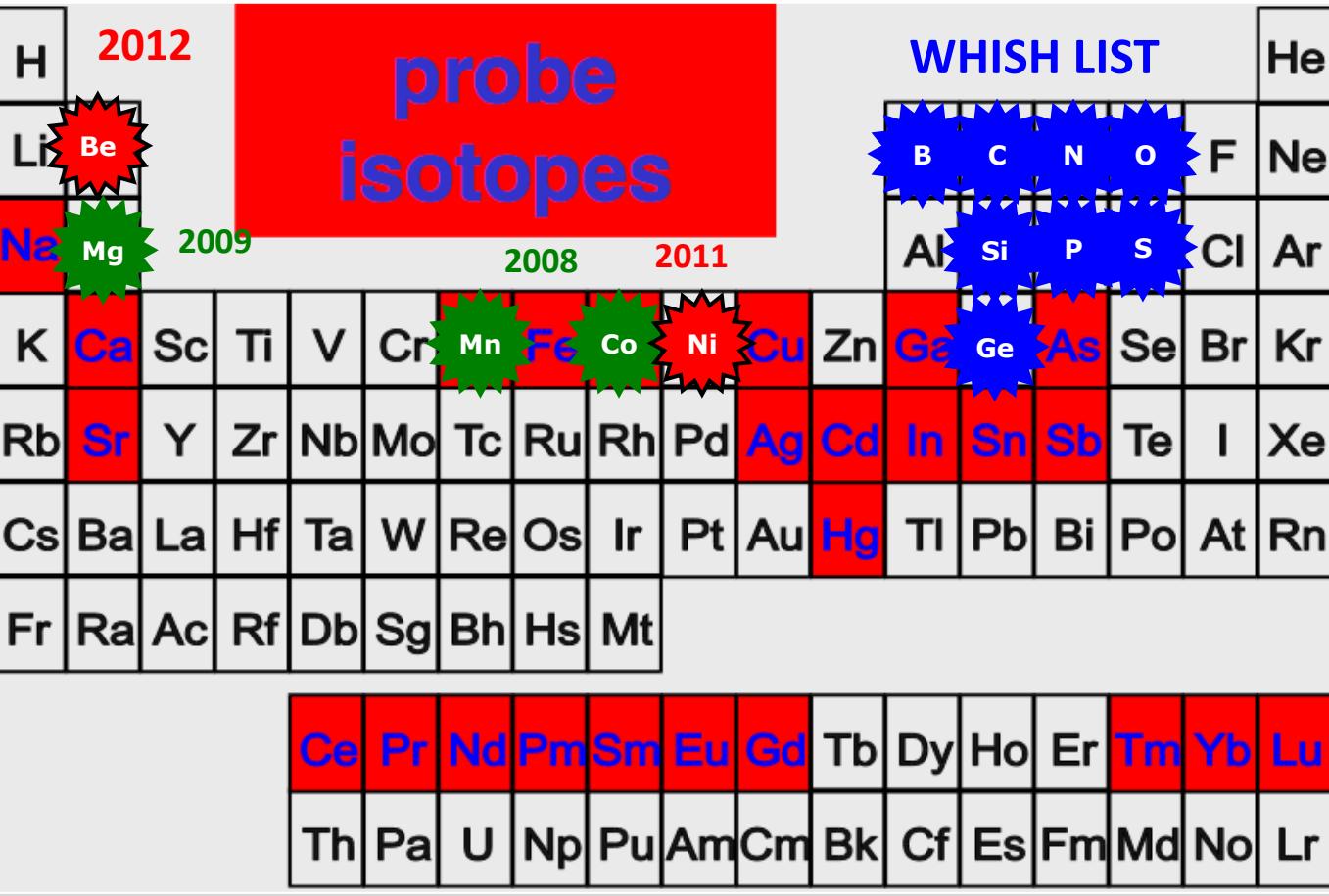
262144
pixels...



512 x 512 55 μm pixels
NEW TIMEPIX
2013 ...



2012 NEW FAST VATAGP7
PAD detector
 $(22 \times 22 = 484 \text{ pads } 1.4 \times 1.4 \text{ mm}^2)$
 $> 5.5 \text{ kHz}$

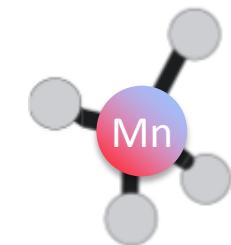
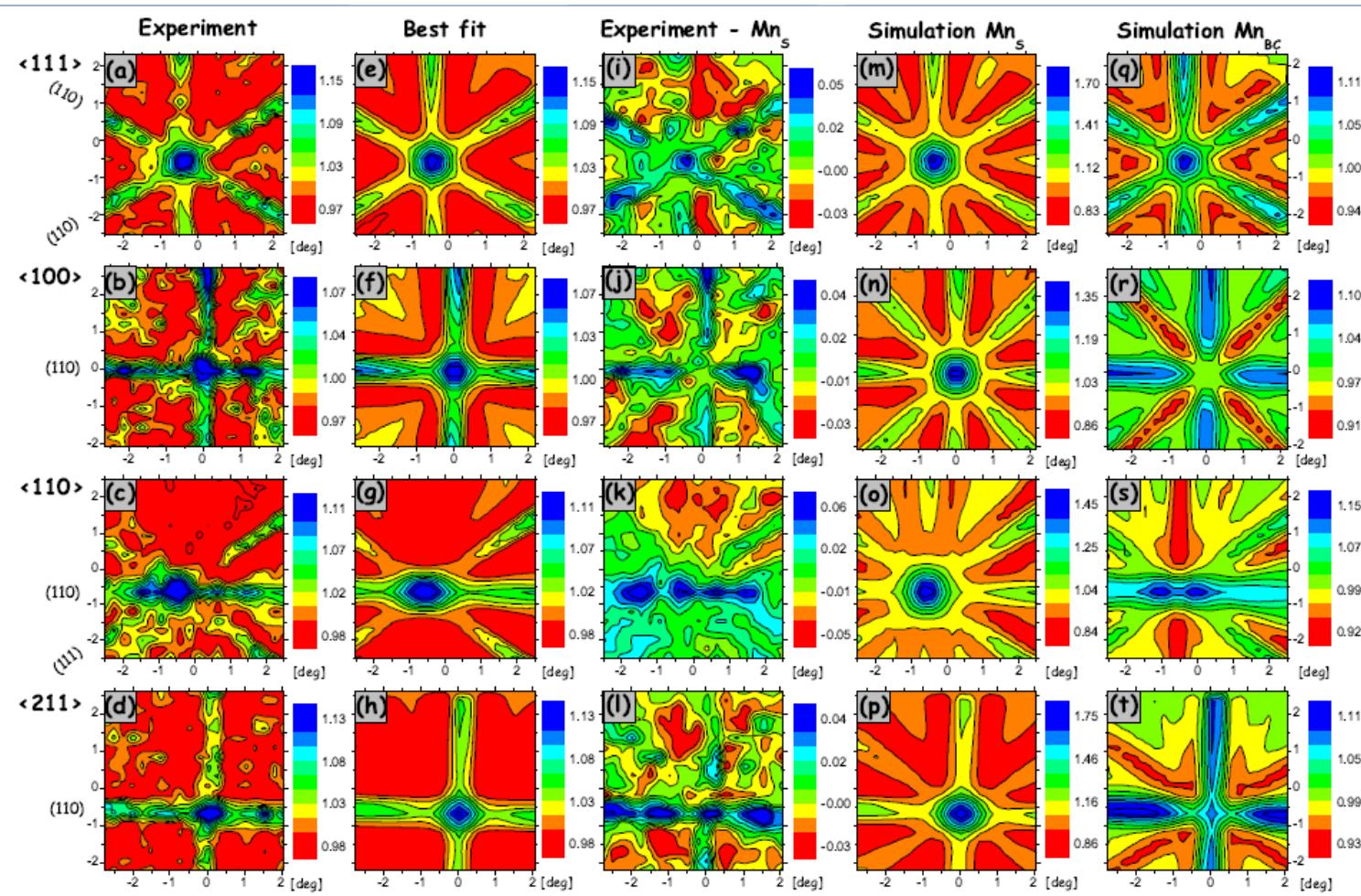


Lattice location study of implanted ^{56}Mn (2.6h) : Ge

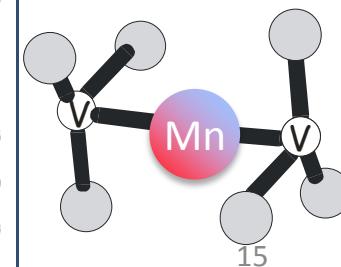
Implantation at 300°C

S. Decoster, U. Wahl et al., Applied Physics Letters 97, 151914 (2010)

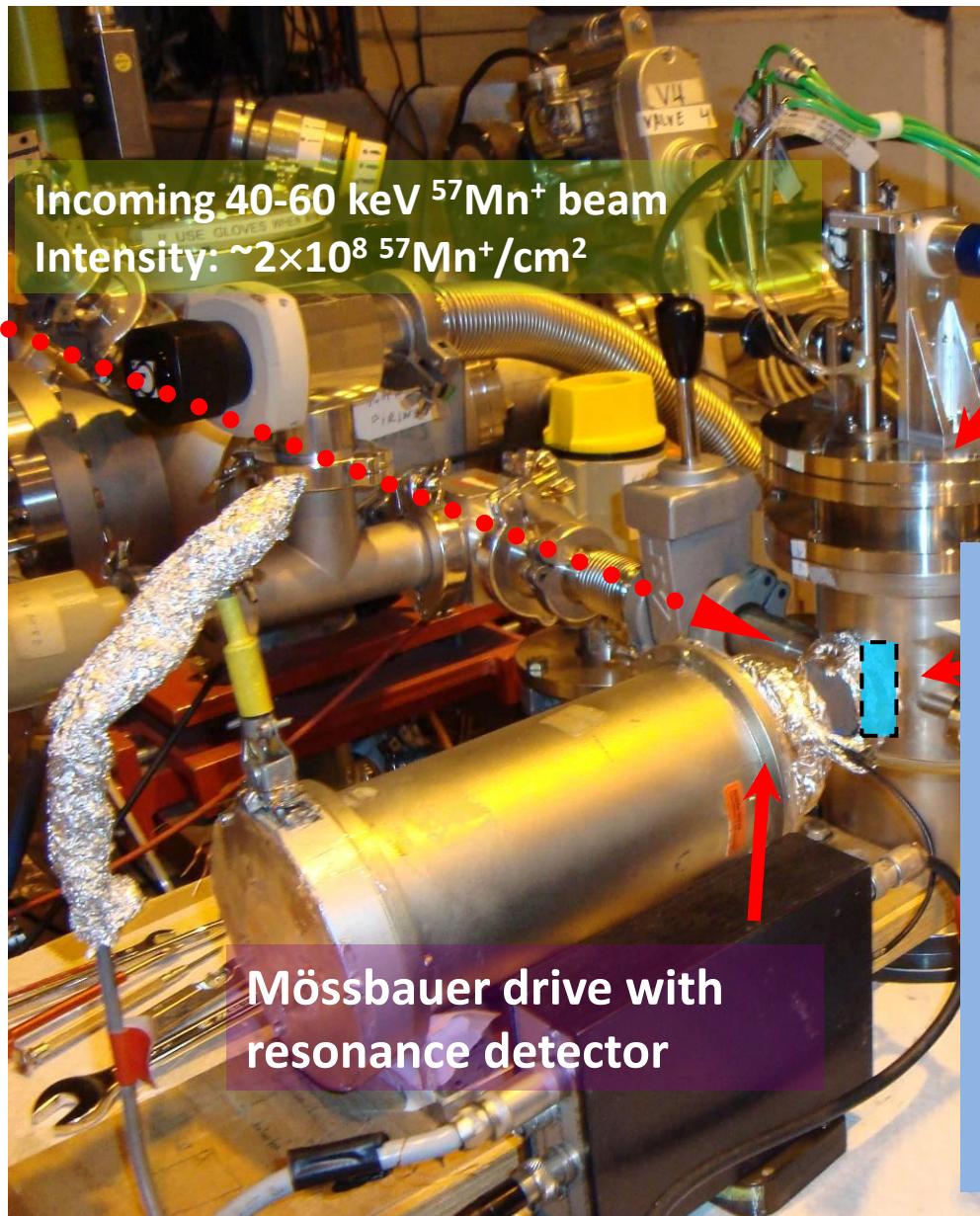
Mn-doped Ge $\leftarrow(?)\rightarrow$ spintronic devices, $\text{Mn}_x\text{Ge}_{1-x}$ ferromagnetic 25K... 116 K,
TC increases linearly 0.6% $<[\text{Mn}] < 3.5\%$.



38(7)%
Mn(S)
+
59(8)%
Mn(BC)



Hyperfine Interactions with Mossbauer spectroscopy



Development of ^{57}Mn beam in late 1990s (with laser ionisation) brought about a new era in Mossbauer experiments at ISOLDE.

- Very clean, intense beam of ^{57}Mn ($>3 \times 10^8 \text{ ions sec}^{-1}$)
- **Allows collection of single Mossbauer spectrum in ~ 3 mins.**
- Able to collect many hundreds over course of a 3 day run.
- **Allows low concentrations of probe atoms to be used ($\sim 10^{-4}\text{At\%}$)**

Fe: ZnO a ferromagnetic semiconductor? (nope!)

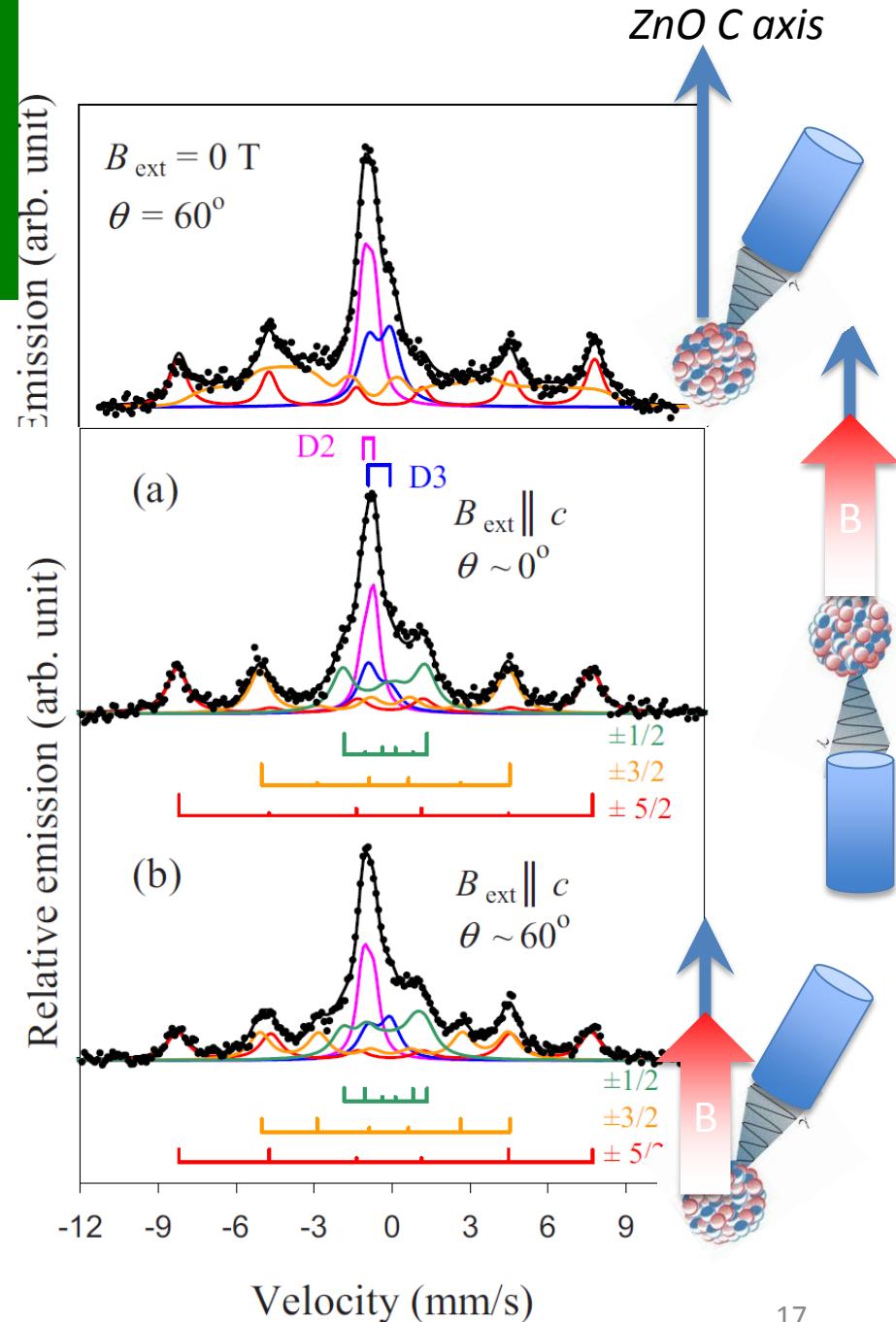
6 fold spectrum: characteristic of magnetic structure (at room temperature!!!).

Results in an external magnetic field show that the spectrum shown to be a **slowly relaxing paramagnetic system**.

Gunnlaugsson *et al* (APL **97** 142501 2010)

After high-dose implantations, precipitates of Fe-III are formed. These form clusters yielding misleading information about the nature of magnetism in ZnO (as reported by many groups over the last number of years).

Gunnlaugsson *et al* APL **100** 042109 2012



Mössbauer periodic table

MOOLDE

Mössbauer Periodic Table

The following table illustrates the Mössbauer Periodic Table, highlighting elements based on the number of observed Mössbauer transitions and isotopes.

Legend:

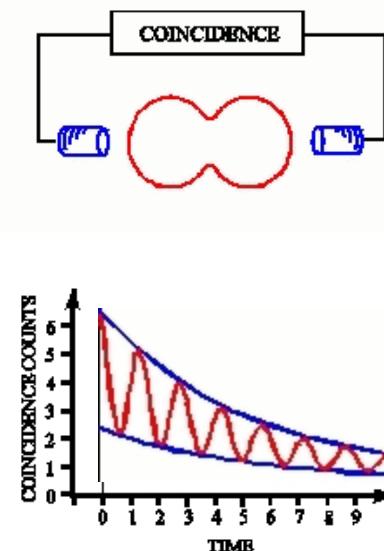
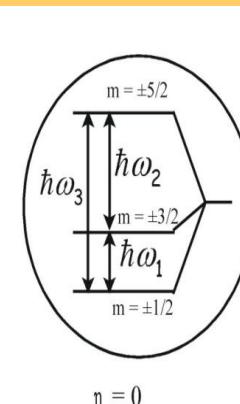
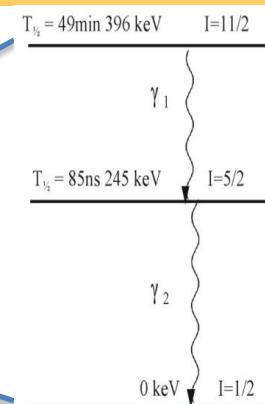
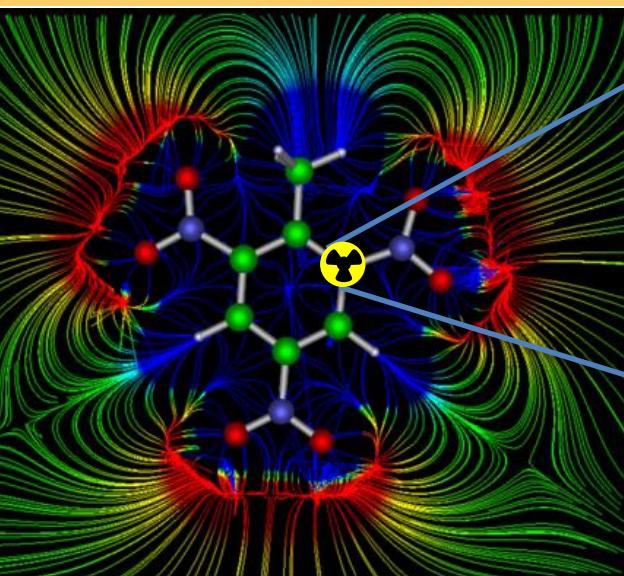
- Green – reproducible good beam**
- Red – low quality beam**

Annotations:

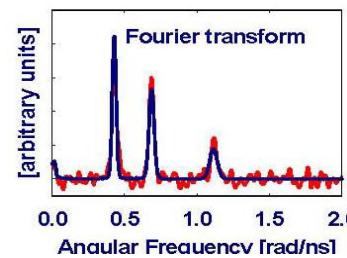
- Fe²**: Number of observed Mössbauer transitions.
- Number of isotopes in which the Mössbauer effect has been observed**: Indicated by the number of isotopes shown in red boxes for Fe, Zn, Ga, Sn, and Hf.
- 67 Zn (62h)**: Red box indicating the number of isotopes for Zn.
- 73Ga (5h)**: Red box indicating the number of isotopes for Ga.
- 181Hf (42d)**: Red box indicating the number of isotopes for Hf.

1																					18
H																					He
Li	Be																				Ne
Na	Mg	3	4	5	6	7	8	9	10	11	12										Ar
K ¹	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni ¹	Cu	Zn	Ga	Ge ²	As	Se	Br				Kr ¹	
Rb	Sr	Y	Zr	Nb	Mo	Tc ¹	Ru ²	Rh	Pd	Ag	Cd	In	Sn	Sb	Te ¹	I ²	Xe ²				
Cs ¹	Ba ¹	La ¹	Hf ⁴	Ta ²	W ⁷	Re ¹	Os ⁶	Ir ⁴	Pt ²	Au ¹	Hg ¹	Tl	Pb	Bi	Po	At	Rn				
Fr	Ra	Ac																			
			Ce	Pr ¹	Nd ²	Pm ¹	Sm ⁶	Eu ⁴	Gd ⁹	Tb ¹	Dy ⁶	Ho ¹	Er ⁵	Tm ¹	Yb ⁶	Lu ¹					
			Th ¹	Pa ¹	U ³	Np ¹	Pu ¹	Am ¹	Cm	Bk	Cf	Es	Fm	Md	No	Lw ¹					

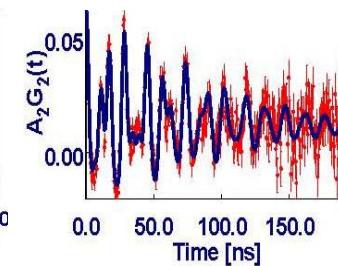
Perturbed angular correlation (PAC) Spectroscopy applied to BIOPHYSICS



Fourier transform



Least χ^2 analysis

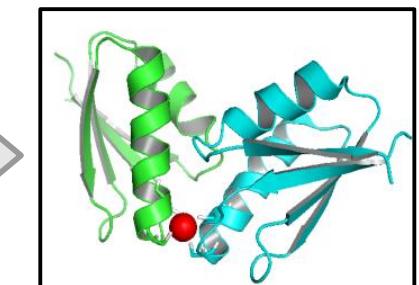


$$A_{22}G_{22}(t) = 2 \frac{W(180^\circ, t) - W(90^\circ, t)}{W(180^\circ, t) + 2W(90^\circ, t)}$$

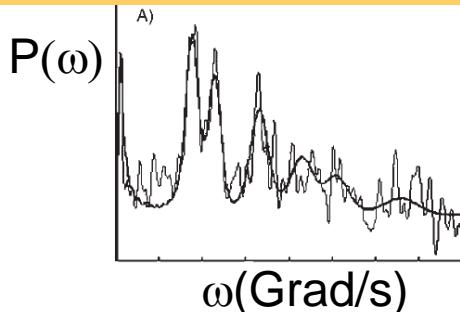


6·180° spectra and 24·90° spectra

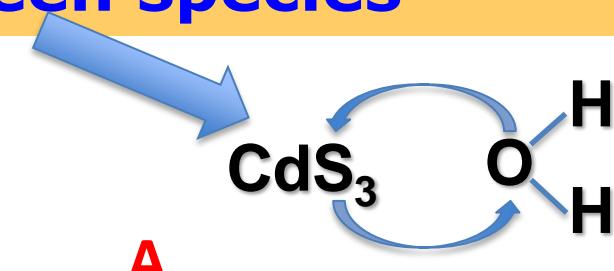
ω_Q and η
+
BASIL model
QM calculations



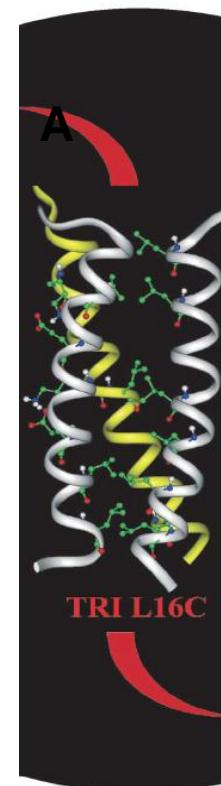
$^{111m}\text{Cd}(48\text{m})$ PAC - Metal Ion Binding Site Structure: Fast inter-conversion between species



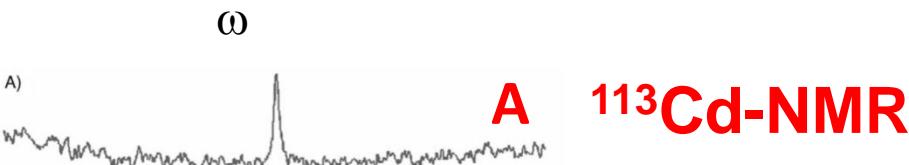
A ^{111m}Cd -PAC



A



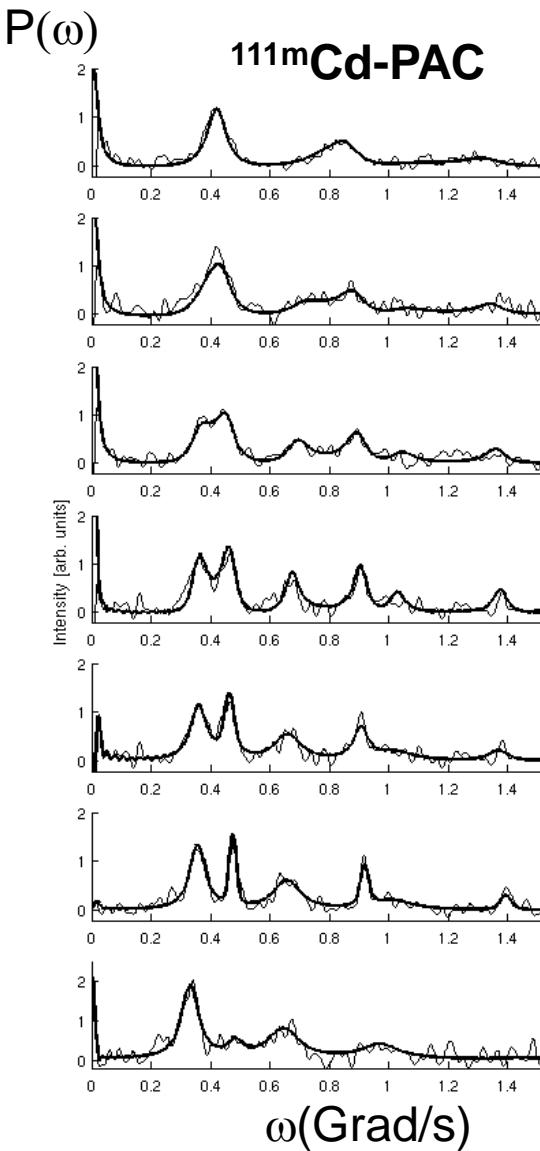
ω



A ^{113}Cd -NMR

Matzapetakis *et al.* J. Am. Chem. Soc. **2002**, 124: 8042; Lee *et al.* Angew. Chem., **2006**, 45: 2864; Peacock *et al.* Proc. Nat. Acad. Sci. **2008**, 105: 16566

^{111m}Cd PAC (48M) - De novo designed heavy metal Ion binding proteins: ns dynamics



50 °C

35 °C

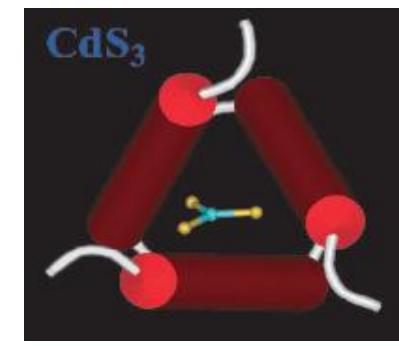
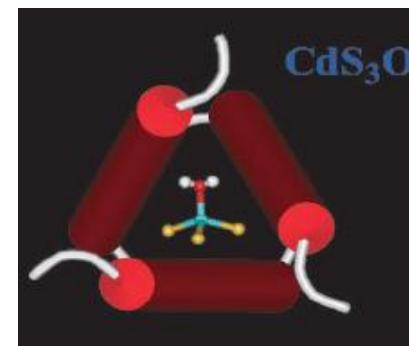
20 °C

1 °C

1 °C

-20 °C

-196 °C



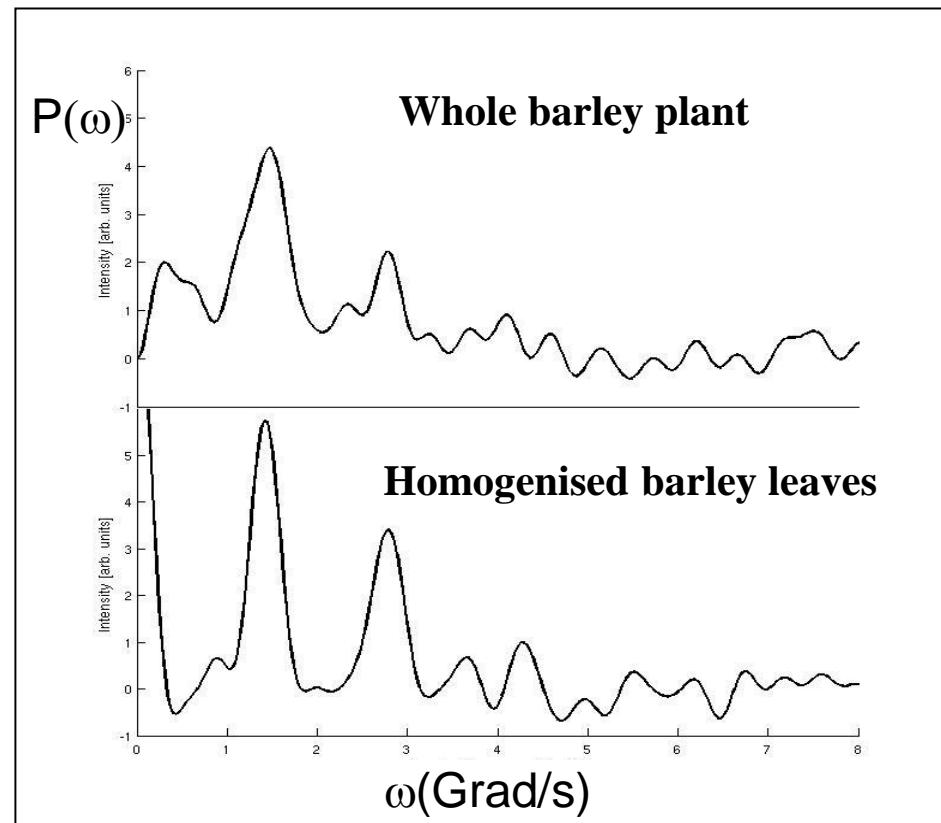
Temp [°C]	τ_1 [ns]	τ_{-1} [ns]
1	52	48
20	42	36
35	28	20
50	19	12

Stachura et al. Manuscript Science in preparation

In vivo experiments Hg(II) binding to barley 199mHg PAC (42M)



Adolph et al. *Chem. Eur. J.*, 2009, 15, 7350 – 7358



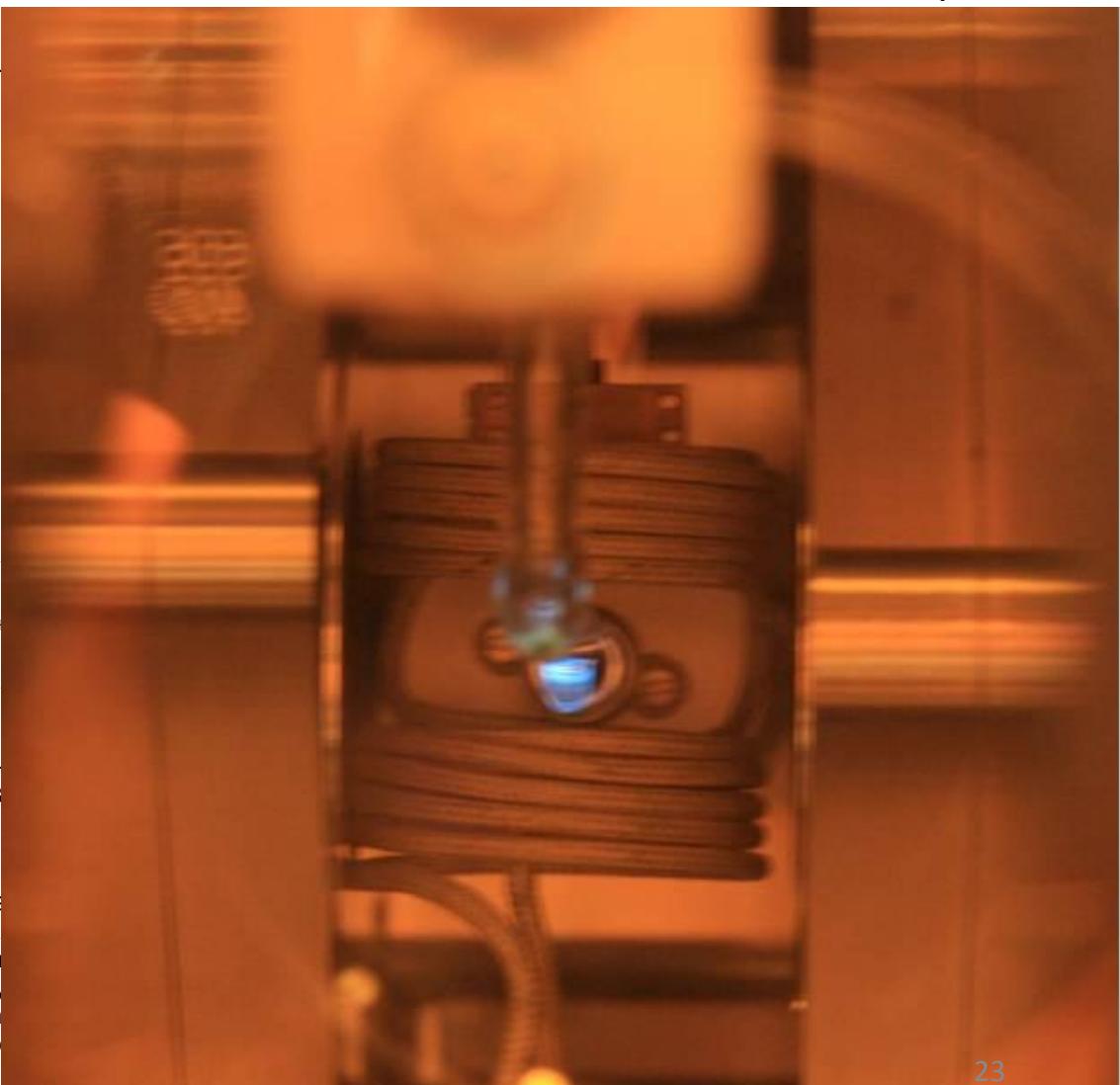
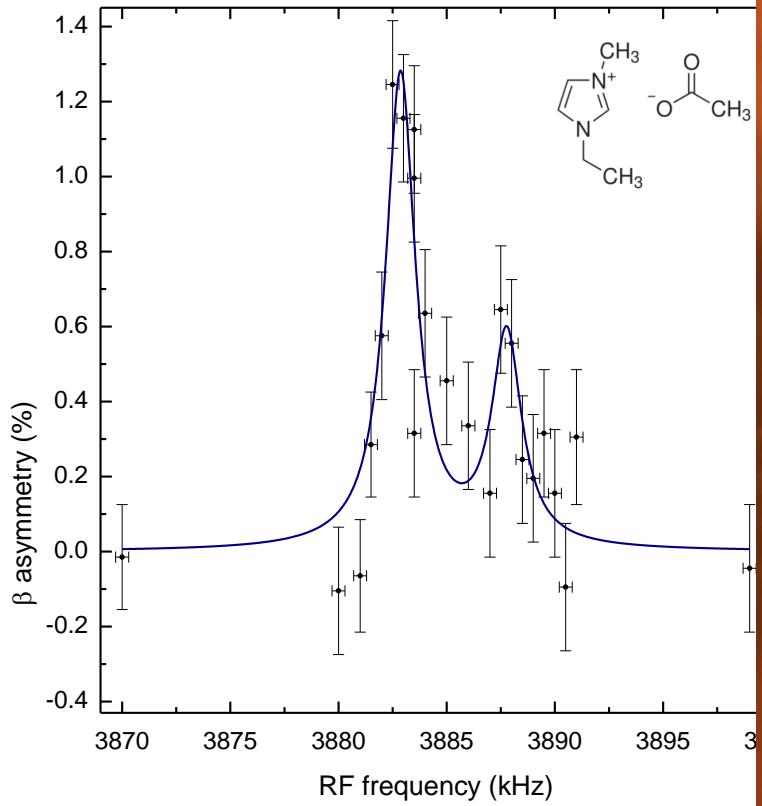
- 5-7 days-old plants
- Plant inserted into test tube.
- Fast uptake of Hg(II) (<1h)
- Bound to large molecules,
similarities to HgS_2 compounds

2012 – first (and successful) $^{31}\text{Mg}^+$

β -NMR experiment applied to soft condensed matter

$^{31}\text{Mg}^+$ implanted into an ionic liquid (EMIM-Ac):

Differential pumping and drop
Mounted @ COLLAPS experiment



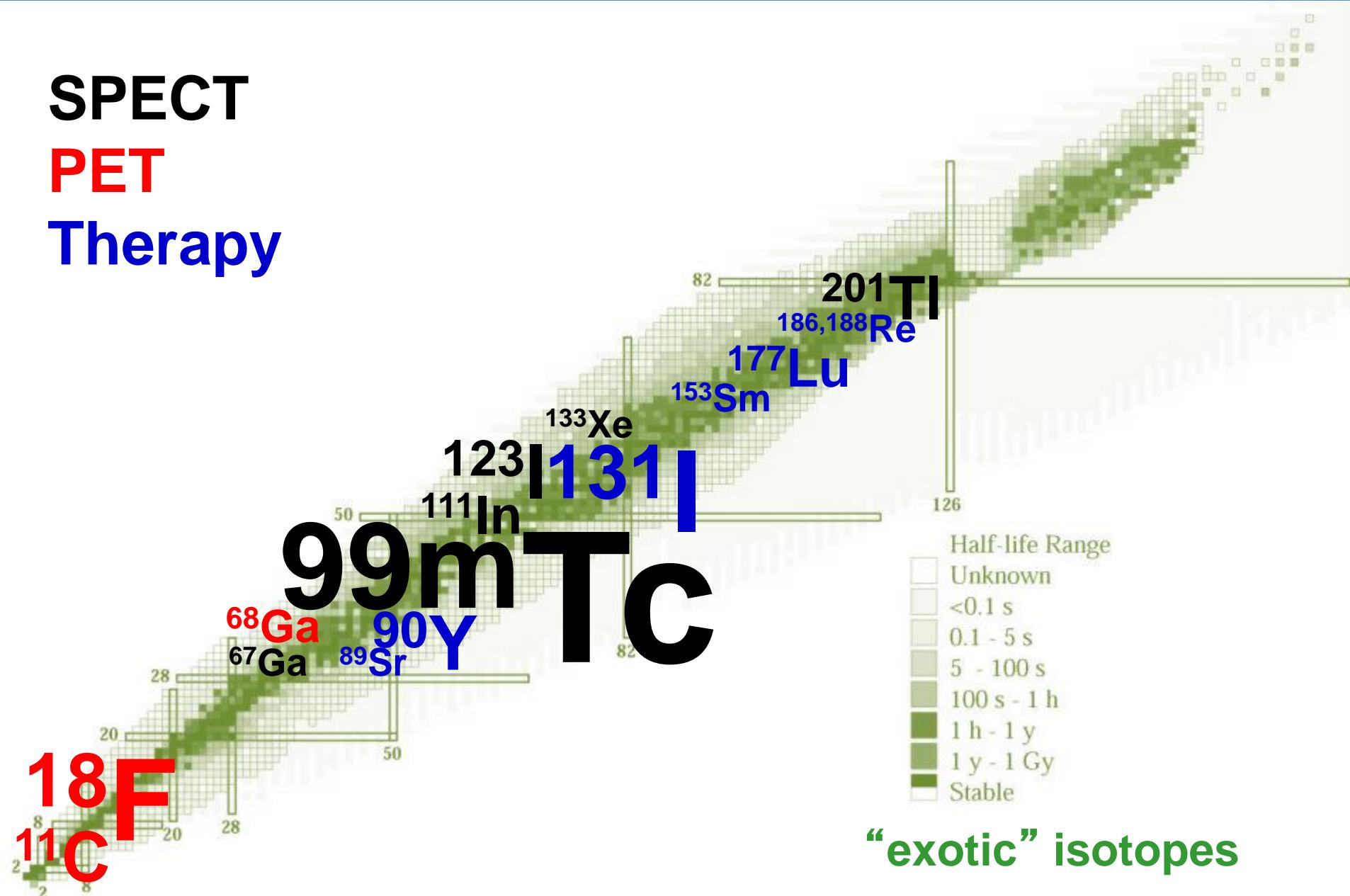
Monika Stachura, University of Copenhagen; Magdalena Kowalewska, CERN, Geneva; Alexander Gottberg, CSIC, Madrid; Klaus Blaum, Max Planck Institute for Nuclear Physics, Heidelberg; Gerda Neyen, Leuven University, (Leuven); Rainer Neugart, Mainz University (Mainz); Deyan Yordanov, Max Planck Institute for Nuclear Physics, Heidelberg; Mark Bissell, Leuven University, (Leuven); Kim Krämer, Max Planck Institute for Nuclear Physics, Heidelberg

Radionuclides for diagnosis and therapy

SPECT

PET

Therapy

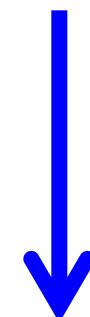


Radionuclides for therapy

Radio-nuclide	Half-life	E mean (keV)	E γ (B.R.) (keV)	Range
Y-90	64 h	934 β	-	12 mm
I-131	8 days	182 β	364 (82%)	3 mm
Lu-177	7 days	134 β	208 (10%) 113 (6%)	2 mm

Established isotopes

Emerging isotopes



localized radiation

Production of non-carrier-added ^{177}Lu

Hf 176 5.26	Hf 177 51 m 1.1 s 18.60	Hf 178 31 a 4.0 s 27.28	Hf 179 25 d 18.7 s 13.62	Hf 180 5.5 h 35.08
σ_{23}	ly 277; 295; 327... σ_{45}	ly 574; 495; 217... σ_{45}	ly 426; 326; +54 123; σ_{46}	ly 454; 363; 124; σ_{46}
	$\sigma_{10^{-7}}$ +1 +32		$\sigma_{0.43}$	$\text{ly} 332;$ 443; 215; 57... β^- σ_{13} $\sigma_{n,\alpha} < 1.3 \cdot 10^{-10}$
Lu 175 97.41	Lu 176 2.59	Lu 177 160.1 d $\beta^- 0.2$ $\gamma 414$ 319; 122 $\sigma_{3.2}$	Lu 178 22.7 m 28.4 m $\beta^- 0.5...$ $\gamma 208$ 113... σ_{1000}	Lu 179 4.6 h $\beta^- 1.2...$ $\gamma 193$ 1341; 1310; 1269... σ_g
σ_{16+8}	3.68 h $\beta^- 1.2...$ $\gamma 307$ 202; 88... σ_{2+2100}	$3.8 \cdot 10^{10} \text{ a}$ $\beta^- 0.6...$ $\gamma 88$ σ^-		$\beta^- 1.4...$ $\gamma 214...$ σ_g
Yb 174 31.83	Yb 175 4.2 d	Yb 176 12 s 12.76	Yb 177 6.5 1.9 h $\beta^- 1.4...$ $\gamma 104$ 228 σ^-	Yb 178 74 m $\beta^- 0.6...$ $\gamma 391; 348$ σ_g
σ_{63}	$\sigma_{n,\alpha} < 0.00002$	$\beta^- 0.5...$ $\gamma 396; 283$ 114...	$\sigma_{3.1}$ $\sigma_{n,\alpha} < 1E-4$	



Irradiation in high flux reactor (e.g. ILL Grenoble),
then chemical separation of ^{177}Lu from stable Yb.

Radionuclides for therapy

Radio-nuclide	Half-life	E mean (keV)	E γ (B.R.) (keV)	Range
Y-90	64 h	934 β	-	12 mm
I-131	8 days	182 β	364 (82%)	3 mm
Lu-177	7 days	134 β	208 (10%) 113 (6%)	2 mm
Tb-161	7 days	154 β 5, 17, 40 e^-	75 (10%)	2 mm 1-30 μm
Tb-149	4.1 h	3967 α	165,..	25 μm
Ge-71	11 days	8 e^-	-	1.7 μm
Er-165	10.3 h	5.3 e^-	-	0.6 μm

cross-fire

Established isotopes

Emerging isotopes

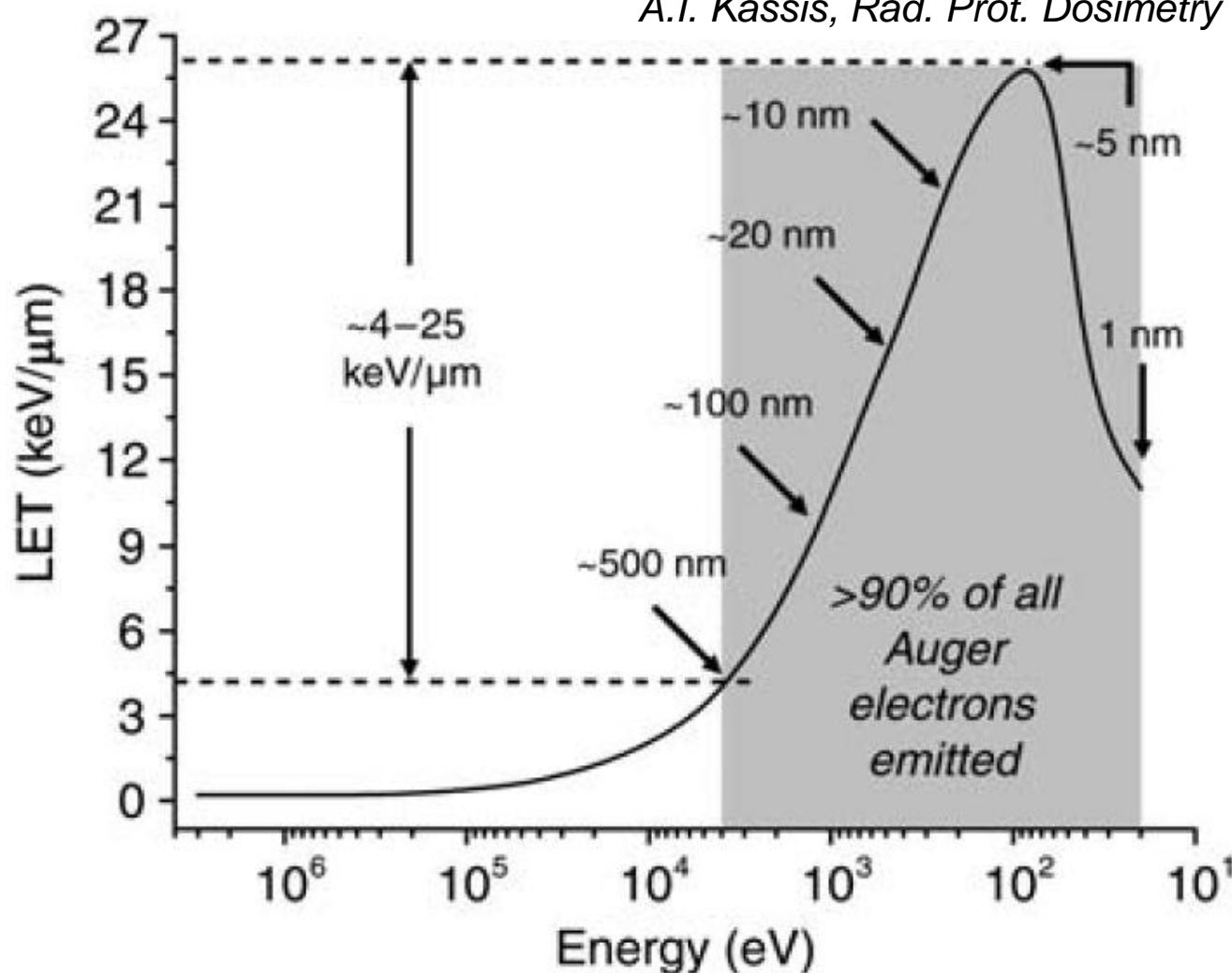
R&D isotopes:
supply-limited!

localized

Modern, better targeted vectors require shorter-range radiation \Rightarrow need for adequate (R&D) radioisotope supply.

Linear Energy Transfer of Auger electrons

A.I. Kassis, Rad. Prot. Dosimetry 143 (2011) 241.



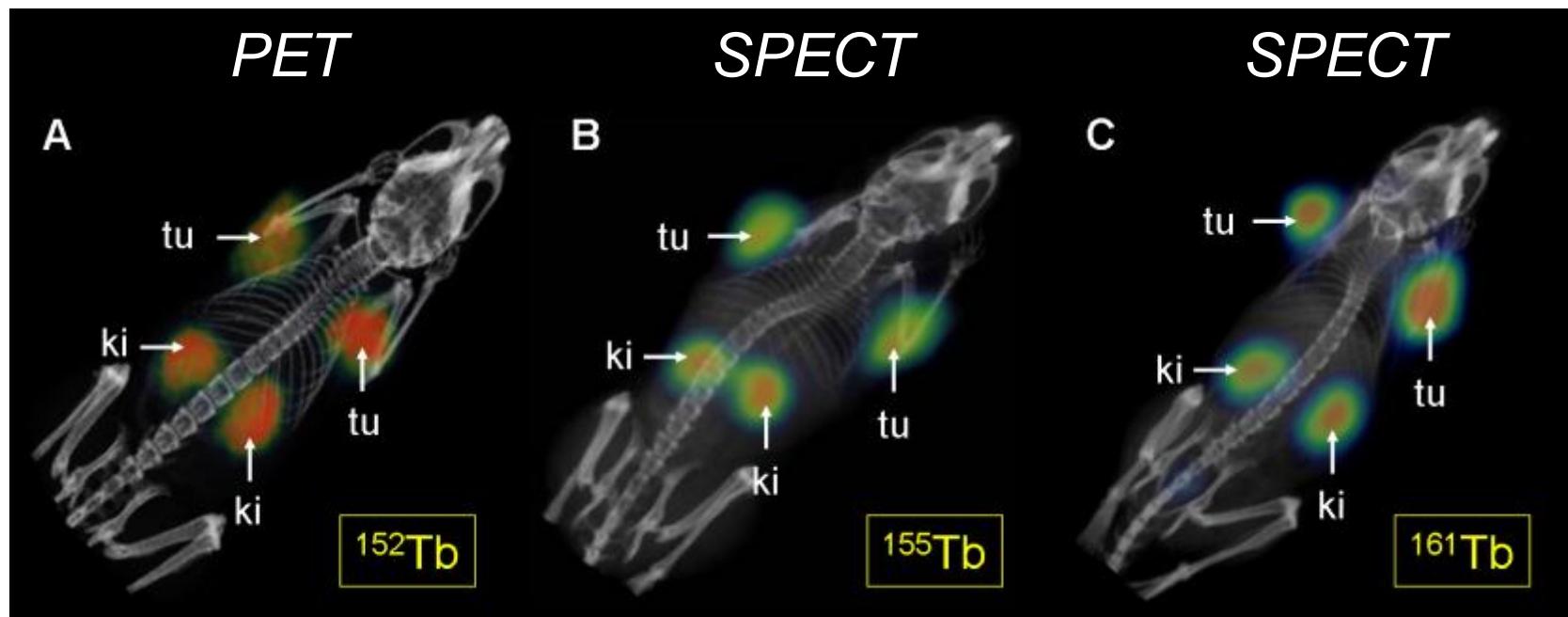
Very targeted therapy (high efficacy/low side effects) possible if “internalizing” vectors (peptides, antibodies,...) are found that penetrate the cancer cell’s nucleus.

Terbium: a unique element for nuclear medicine



Dy 150 7.2 m $\epsilon: \beta^+$ $\alpha: 4.23$ $\gamma: 387$ $\sigma: 100$	Dy 151 17 m $\epsilon: \alpha: 4.07$ $\gamma: 386; 49;$ $546; 176...$ $\sigma: 100$	Dy 152 2.4 h $\epsilon: \beta^+$ $\alpha: 3.63$ $\gamma: 257$ $\sigma: 100$	Dy 153 6.29 h $\epsilon: \beta^+$ $\alpha: 3.46$ $\gamma: 81; 214;$ $100; 254$ $\sigma: 2.87$	Dy 154 $3.0 \cdot 10^6$ a $\epsilon: \beta^+$ $\alpha: 0.9$ $\gamma: 227$ $\sigma: 0.009$	Dy 155 10.0 h $\epsilon: \beta^+$ $\alpha: 0.9; 1.1...$ $\gamma: 227$ $\sigma: 0.009$	Dy 156 0.056 $\epsilon: \beta^+$ $\alpha: < 0.009$ $\gamma: 226$ $\sigma: 0.009$	Dy 157 8.1 h $\epsilon: \beta^+$ $\alpha: 0.9$ $\gamma: 326$ $\sigma: 0.009$	Dy 158 0.095 $\epsilon: \beta^+$ $\alpha: 0.9$ $\gamma: 58; \alpha^-$ $\sigma: 8000$	Dy 159 144.4 d $\epsilon: \beta^+$ $\alpha: 60$ $\gamma: 58; \alpha^-$ $\sigma: 0.0003$	Dy 160 2.329 $\epsilon: \beta^+$ $\alpha: 600$ $\gamma: 58; \alpha < 1E-6$ $\sigma: 1.70$	Dy 161 18.889 $\epsilon: \beta^+$ $\alpha: 600$ $\gamma: 58; \alpha < 1E-6$ $\sigma: 1.70$	Dy 162 25.475 $\epsilon: \beta^+$ $\alpha: 600$ $\gamma: 58; \alpha < 1E-6$ $\sigma: 1.70$	
Tb 149 4.2 m $\epsilon: \beta^+$ $\alpha: 3.97$ $\gamma: 395; 198;$ $179; 186;$ $185; 385$	Tb 150 5.8 m $\epsilon: \beta^+$ $\alpha: 3.1;$ $\gamma: 405;$ $37; 341...$ $100; 349;$ $300; 287;$ $621; 411...$	Tb 151 25 s $\epsilon: \beta^+$ $\alpha: 3.1;$ $\gamma: 405;$ $37; 341...$ $100; 349;$ $300; 287;$ $621; 411...$	Tb 152 42 m $\epsilon: \beta^+$ $\alpha: 3.49$ $\gamma: 394;$ $212; 211;$ $10; 102; 83...$	Tb 153 17.5 h $\epsilon: \beta^+$ $\alpha: 3.41$ $\gamma: 255;$ $212; 211;$ $10; 102; 83...$	Tb 154 2.34 d $\epsilon: \beta^+$ $\alpha: 2.93$ $\gamma: 248;$ $212; 211;$ $10; 102; 83...$	Tb 155 5.32 d $\epsilon: \beta^+$ $\alpha: 2.87; 105;$ $\gamma: 87; 106;$ $180; 262...$	Tb 156 4 h? $\epsilon: \beta^+$ $\alpha: 2.48$ $\gamma: 248;$ $193; 192;$ $142; 140;$ $540; 540...$	Tb 157 54 h $\epsilon: \beta^+$ $\alpha: 2.48$ $\gamma: 193; 192;$ $142; 140;$ $540; 540...$	Tb 158 99 a $\epsilon: \beta^+$ $\alpha: 2.48$ $\gamma: (54)$ $\sigma: 7$	Tb 159 10.5 s $\epsilon: \beta^+$ $\alpha: 2.48$ $\gamma: 193; 192;$ $142; 140;$ $540; 540...$	Tb 160 180 s $\epsilon: \beta^+$ $\alpha: 2.48$ $\gamma: 193; 192;$ $142; 140;$ $540; 540...$	Tb 161 100 $\epsilon: \beta^+$ $\alpha: 2.48$ $\gamma: 193; 192;$ $142; 140;$ $540; 540...$	Tb 162 100 $\epsilon: \beta^+$ $\alpha: 2.48$ $\gamma: 193; 192;$ $142; 140;$ $540; 540...$
Gd 148 74.6 a $\epsilon: \alpha: 3.183$ $\sigma: 14000$	Gd 149 9.28 d $\epsilon: \alpha: 3.016$ $\gamma: 150; 299;$ $347...$	Gd 150 $1.8 \cdot 10^6$ a $\epsilon: \alpha: 2.60$ $\gamma: 154; 243;$ $175...$	Gd 151 120 d $\epsilon: \alpha: 2.60$ $\gamma: 154; 243;$ $175...$	Gd 152 0.20 $\epsilon: 1.1 \cdot 10^{14}$ a $\alpha: 2.14; \gamma: 700$ $\sigma_{\alpha, \gamma} < 0.007$	Gd 153 239.47 d $\epsilon: \alpha: 0.20$ $\gamma: 20000$ $\sigma_{\alpha, \gamma} < 0.003$	Gd 154 2.18 $\epsilon: \alpha: 0.20$ $\gamma: 20000$ $\sigma_{\alpha, \gamma} < 0.008$	Gd 155 14.80 $\epsilon: \alpha: 0.20$ $\gamma: 20000$ $\sigma_{\alpha, \gamma} < 0.008$	Gd 156 20.47 $\epsilon: \alpha: 0.20$ $\gamma: 254000$ $\sigma_{\alpha, \gamma} < 0.05$	Gd 157 15.65 $\epsilon: \alpha: 0.20$ $\gamma: 254000$ $\sigma_{\alpha, \gamma} < 0.05$	Gd 158 24.84 $\epsilon: \alpha: 0.20$ $\gamma: 254000$ $\sigma_{\alpha, \gamma} < 0.05$	Gd 159 18.48 h $\epsilon: \alpha: 0.20$ $\gamma: 254000$ $\sigma_{\alpha, \gamma} < 0.05$	Gd 160 21.86 $\epsilon: \alpha: 0.20$ $\gamma: 254000$ $\sigma_{\alpha, \gamma} < 0.05$	Gd 161 1.5 $\epsilon: \alpha: 0.20$ $\gamma: 254000$ $\sigma_{\alpha, \gamma} < 0.05$

Imaging Studies Using PET and SPECT



C. Müller et al., J. Nucl. Med. (2012), in press.

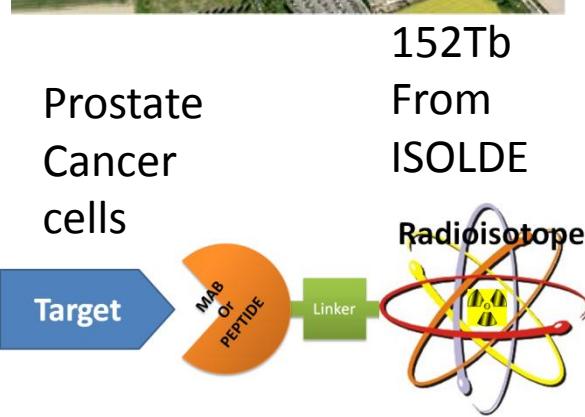
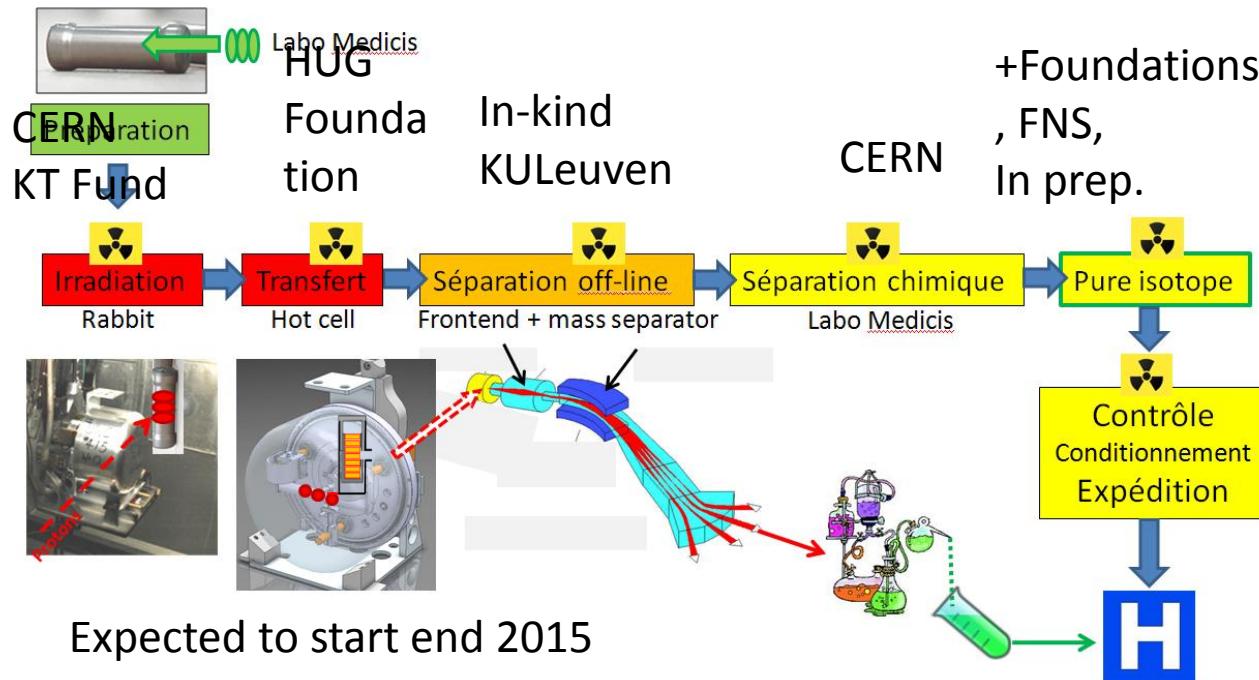
IS528 collaboration: supported by ENSAR, Swiss National Science Foundation and Swiss South African Joint Research Program.



CERN-MEDICIS: Medical isotopes collected from ISOLDE

R. Catherall, M. Dias, T. Giles, Z. Lawson, S. Marzari, T. Stora (CERN)

Dr. Forni (Clin. Carouge), L. Vouga, Prof. P. Morel, Prof. L. Buehler, Prof. Y. Seimbille, Prof. O. Ratib (HUG, Geneva), Prof. D. Hanahan (ISREC-EPFL, Lausanne), Prof. J. Prior, Dr. F. Buchegger (CHUV, Lausanne), Prof. M. Huyse, Prof. P. van Duppen (Univ. Leuven), Prof. S. Lahiri (SINP, Kolkata)



152Tb
From
ISOLDE



The (potential) role of ISOL in nuclear medicine

1. Samples of R&D isotopes which are not commercially available or easily producible by other means.
2. Isotopes with ultimate specific activity for R&D, e.g. studies of efficacy versus specific activity.
3. Isotopes that are best produced by spallation (^{149}Tb ,...).

Existing ISOL beams are sufficiently intense for preclinical studies, in certain cases even for clinical studies.

**How to organize R&D with RIBs in nuclear medicine?
Physicists are used to “travel to the isotopes”,
but isotopes must “travel to physicians and patients”.**

CONCLUSIONS

“Applications” of EXOCTIC radioactive isotopes

- ❖ Specific areas are identified:

Life Sciences

Materials

Soft Matter

Chemistry...

- ❖ The methods follow the needs with progressing quality...

- ❖ Viability and Visibility of “Applications”

depend at the long term from diversifying and optimizing
RIB infrastructures with:

Dedicated BEAM TIME and BEAM LINES

Dedicated LABORATORY SPACE

...the future of “Applications” depend very much on the concept
of the next generation of RIB facilities

Acknowledgments

To the



organizers !

... to colleagues and collaborators!

- V. Amaral
- L. Amorim
- Y. Blumenfeld
- S. Decoster
- M. Deicher
- A. Fenta
- J.N. Gonçalves
- A. Göttberg
- H. Gunnlaugsson
- K. Johnston
- U. Köster
- M. Kowalska
- A. L. Lopes
- T. Mendonça
- L. Pereira
- M. Stachura
- T. Stora
- U. Wahl
- *and The ISOLDE collaboration*