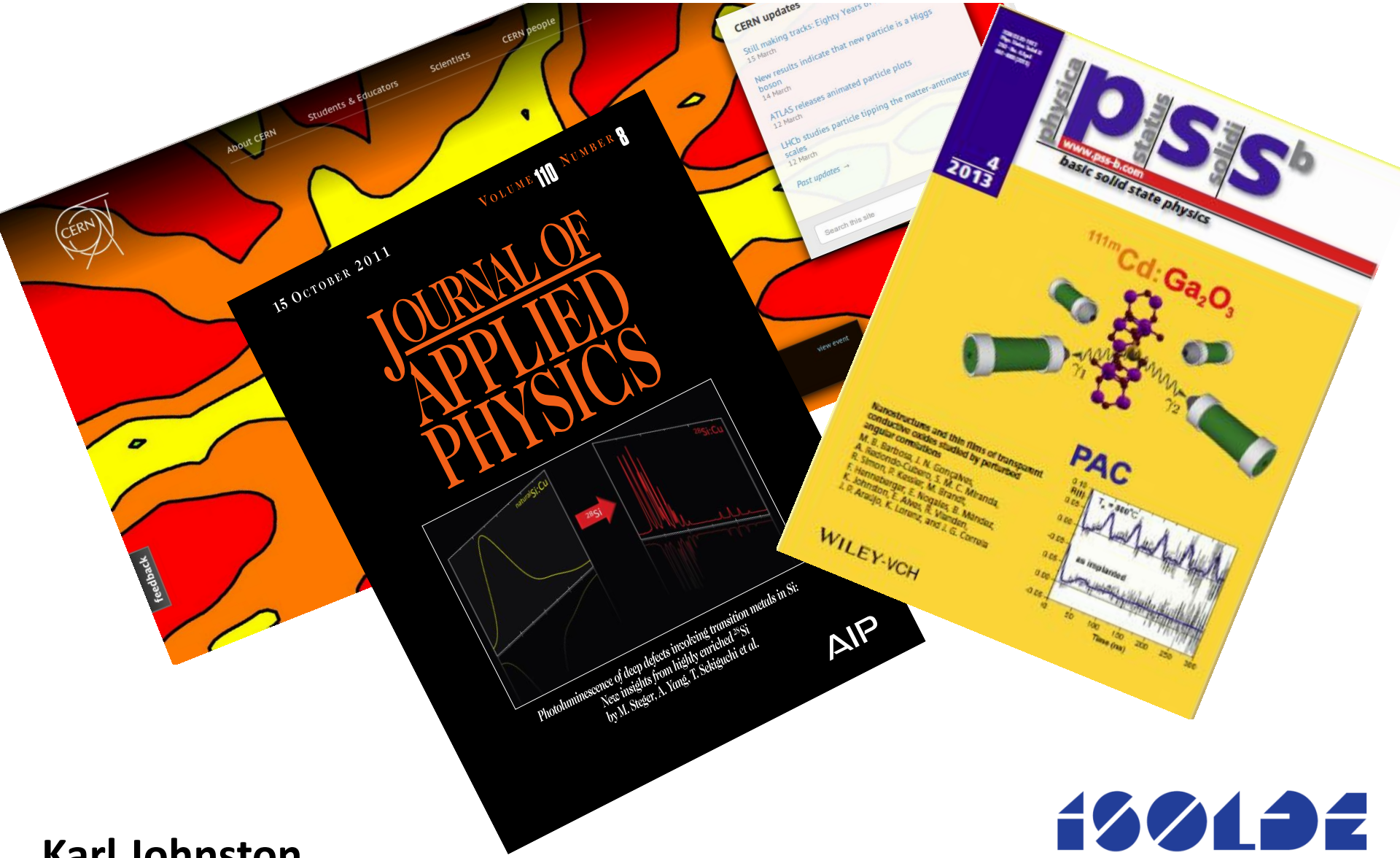
Status report of Solid State Physics, Biophysics and Collections at ISOLDE



Karl Johnston

Outline

- Summary of the materials/systems under study
- Overview of how the various techniques are sub-divided between experiments.
- Main results from experiments: semiconductors; Materials; biophysics; medicine; “miscellaneous”…
- Request for retaining shifts
- Brief addendum to IS486
- End

Variety!

Semiconductors

1. IS432/450
2. IS453
3. IS481
4. IS486
5. IS489
6. IS492
7. IS501
8. IS544

- Si
- Ge
- CdTe
- ZnO
- AlN
- InN
- Ga_2O_3

Biophysics/chemistry

12. IS488

- Model systems
- Proteins: designed and natural

Medicine

13. IS528

- Innovative isotopes for treatment/imaging: **Tb**

Multiferroic/nanomaterials/misc

9. IS487
10. IS514
11. IS515

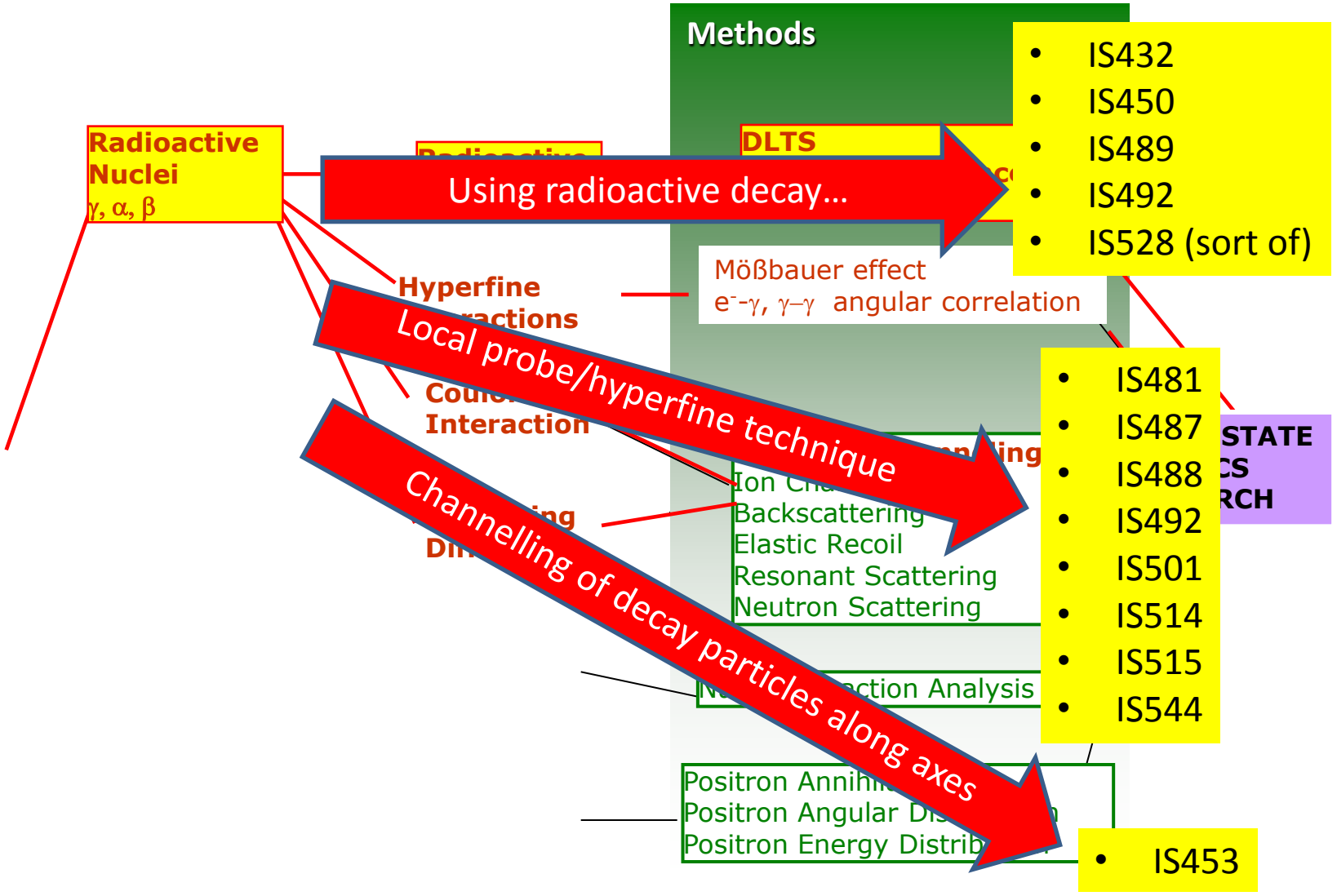
- $RMNO_3$
- Spinels $CdCr_2S_4$
- Intermetallic compounds
- Magnetic Nanoparticles

Collections (e.g. neutrino physics)

14. IS500
15. IS533

- Long-lived sources for calibration of experiment, ^{83}Rb

Applying radioactivity to solid state physics

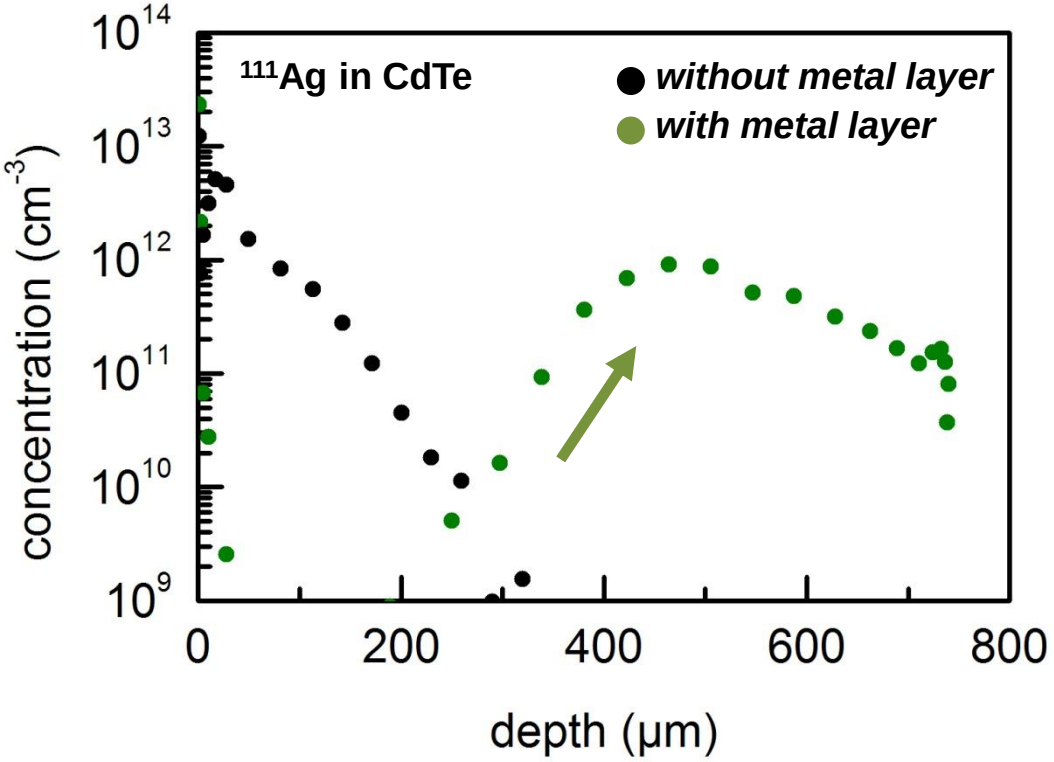


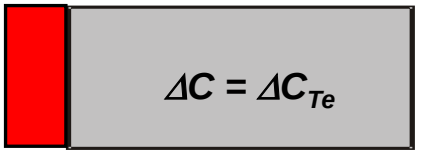
IS489

Influence of metal layers on diffusion…

Diffusion without layer at 500 K

Diffusion with Cu layer at 500 K





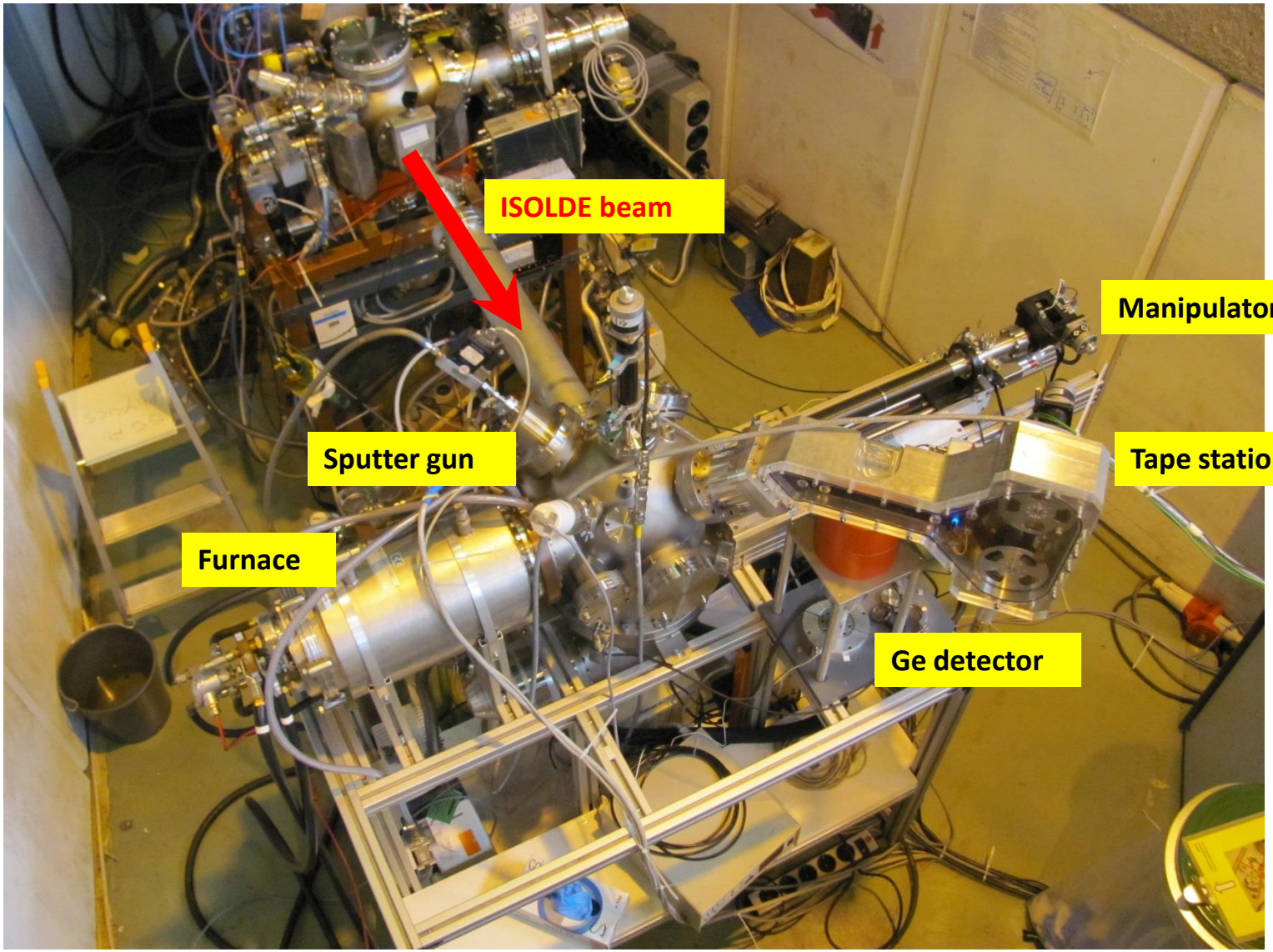
Metal layers can initiate uphill diffusion

(H. Wolf et al., Appl. Phys. Lett. 100 (2012) 171915)

IS489

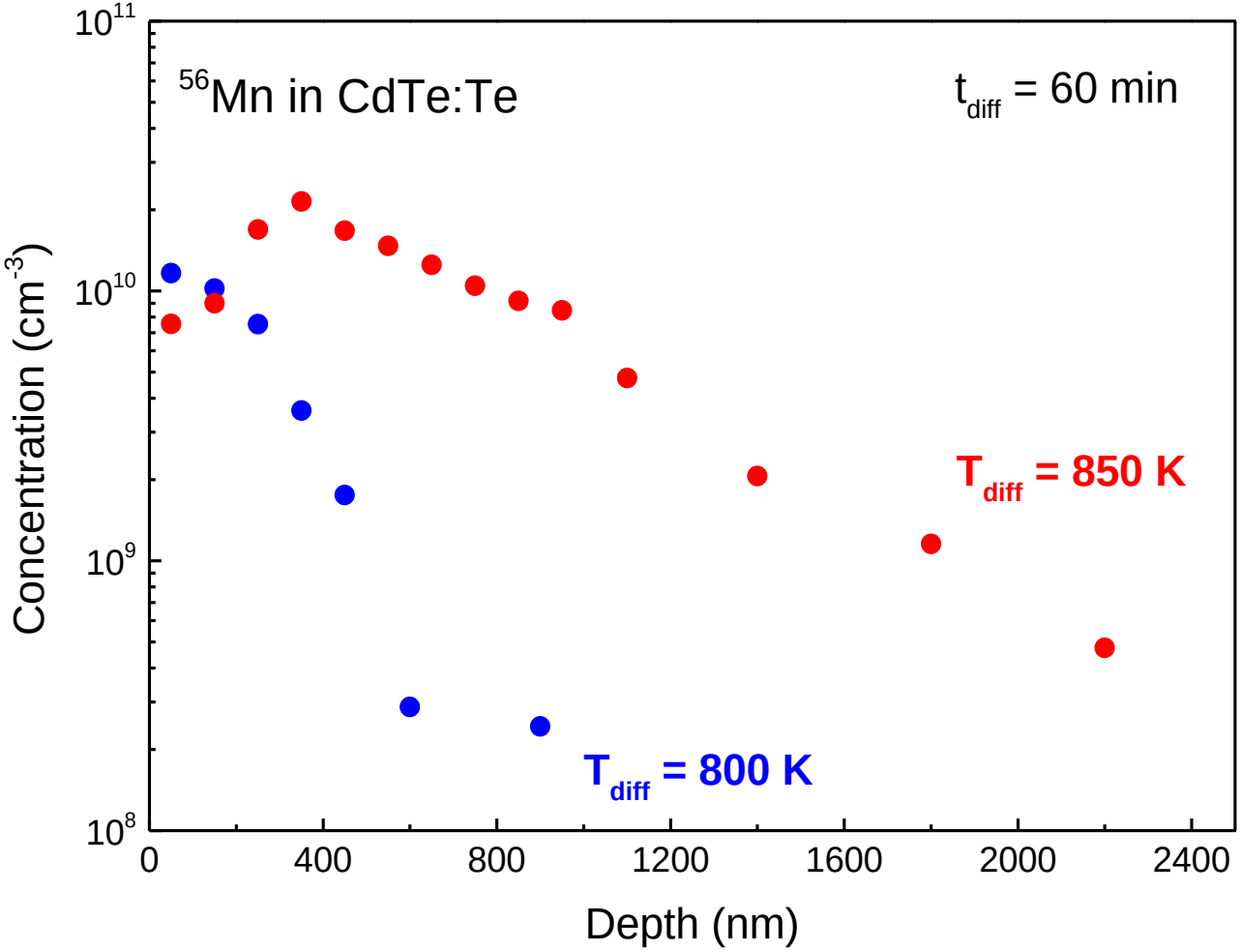
On-line diffusion chamber at ISOLDE

2012

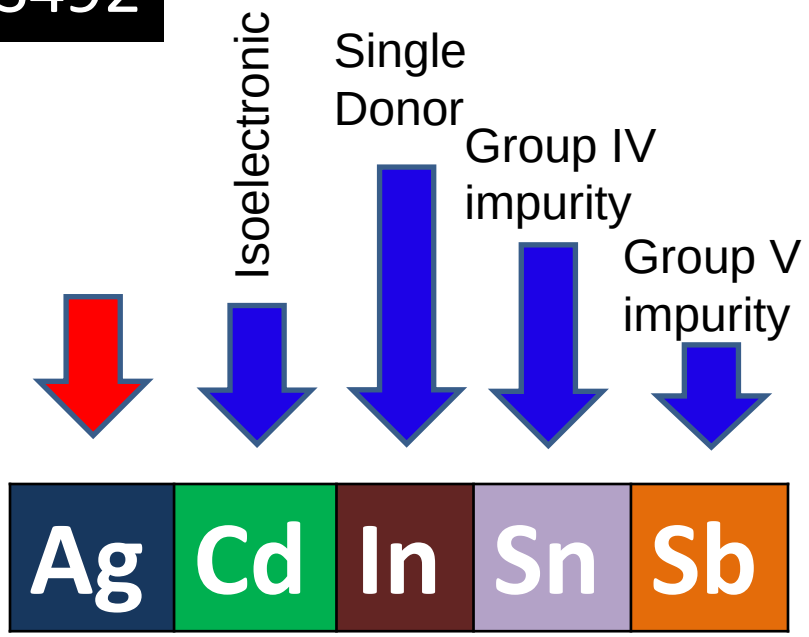


IS489

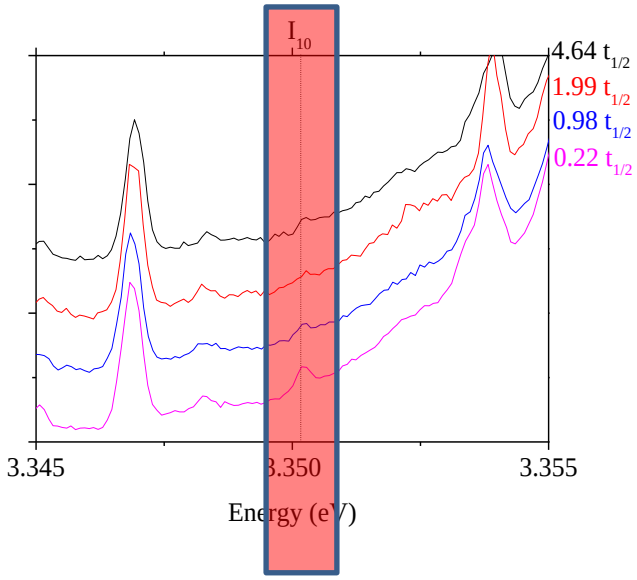
Commissioning of online diffusion chamber…Diffusion of metals in CdTe

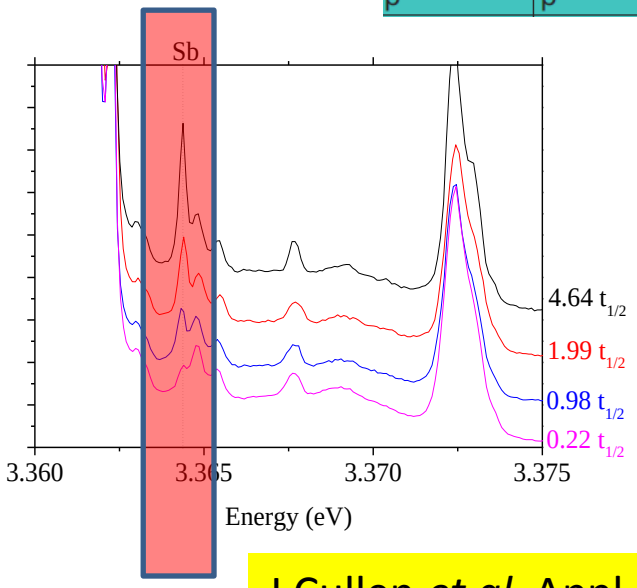


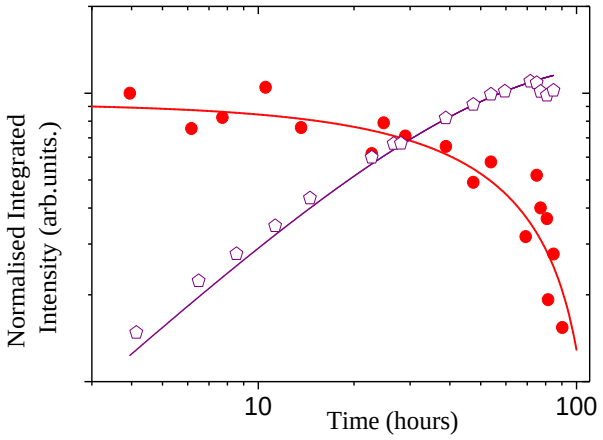
IS492



Sb121 5/2+ * 57.36	**Sb122** 2.70 d 2- * EC,β-	**Sb123** 7/2+ 42.64	**Sb124** 60.20 d 3- * β-	**Sb125** 2.7582 y 7/2+ * β-
Sn120 0+ * 32.59	**Sn121** 27.06 h 3/2+ * β-	**Sn122** 0+ * 4.63	**Sn123** 129.2 d 11/2- * β-	**Sn124** 0+ * 5.79
In119 2.4 m 9/2+ * β-	**In120** 3.08 s 1+ * β-	**In121** 23.1 s 9/2+ * β-	**In122** 1.5 s 1+ * β-	**In123** 5.98 s 9/2+ * β-
Cd118 50.3 m 0+ β-	**Cd119** 2.69 m 3/2+ * β-	**Cd120** 50.80 s 0+ β-	**Cd121** 13.5 s (3/2+) * β-	**Cd122** 5.24 s 0+ β-
Ag117 72.8 s (1/2-) * β-	**Ag118** 3.76 s (1)- * β-	**Ag119** 2.1 s (7/2+) * β-	**Ag120** 1.23 s * β-	**Ag121** 0.78 s (7/2+) β-n



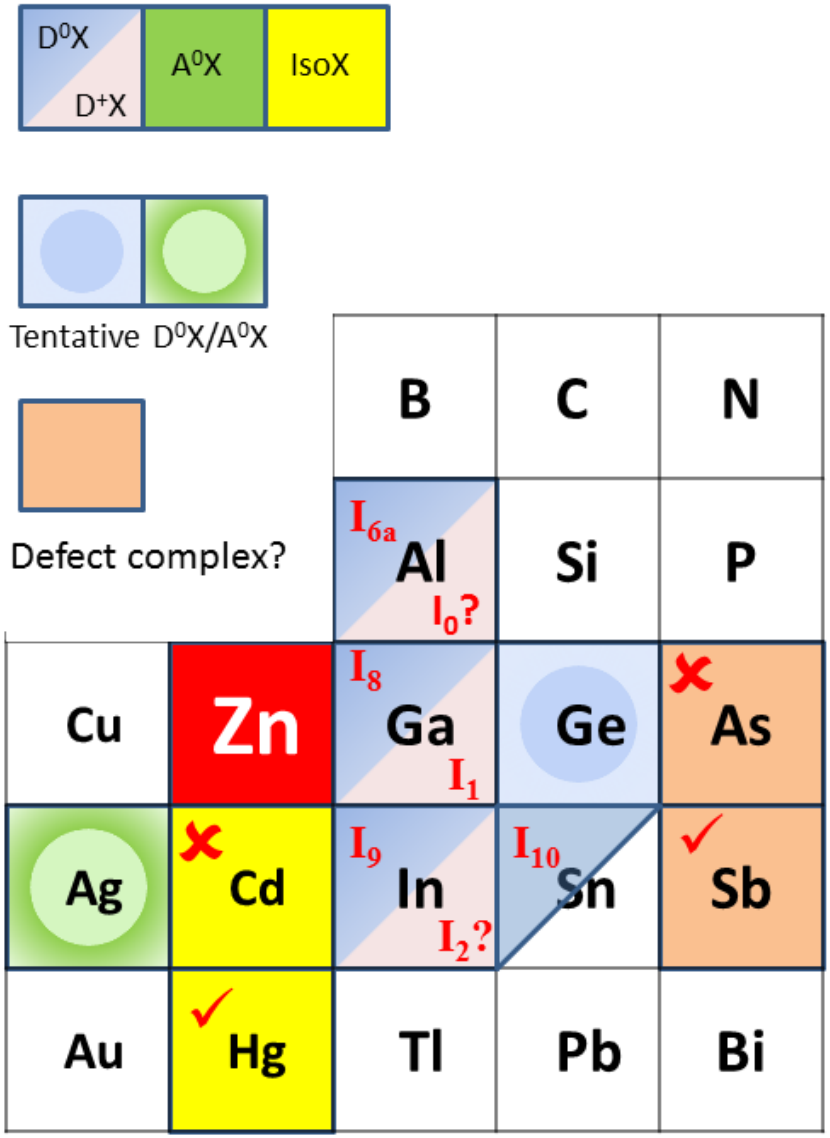




J Cullen *et al* Appl. Phys. Lett. **102** 192110 (2013)

Radiotracer PL has allowed for the full classification of the dominant impurities in ZnO

IS492

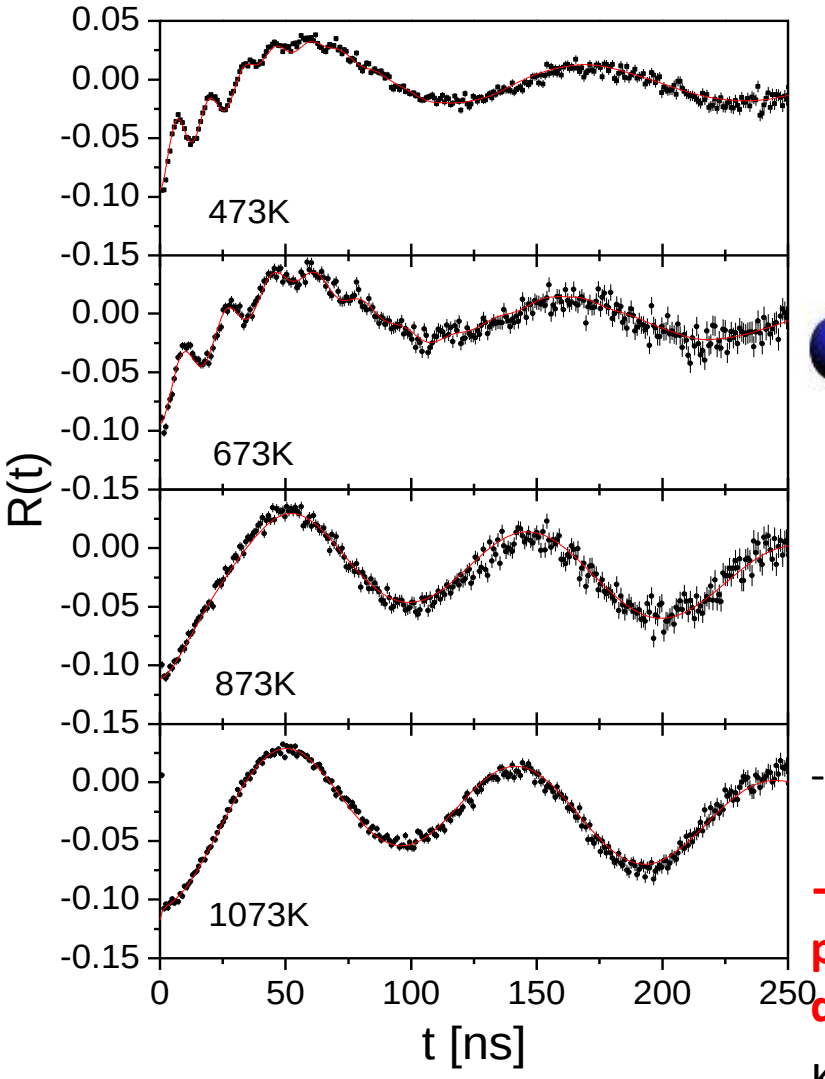


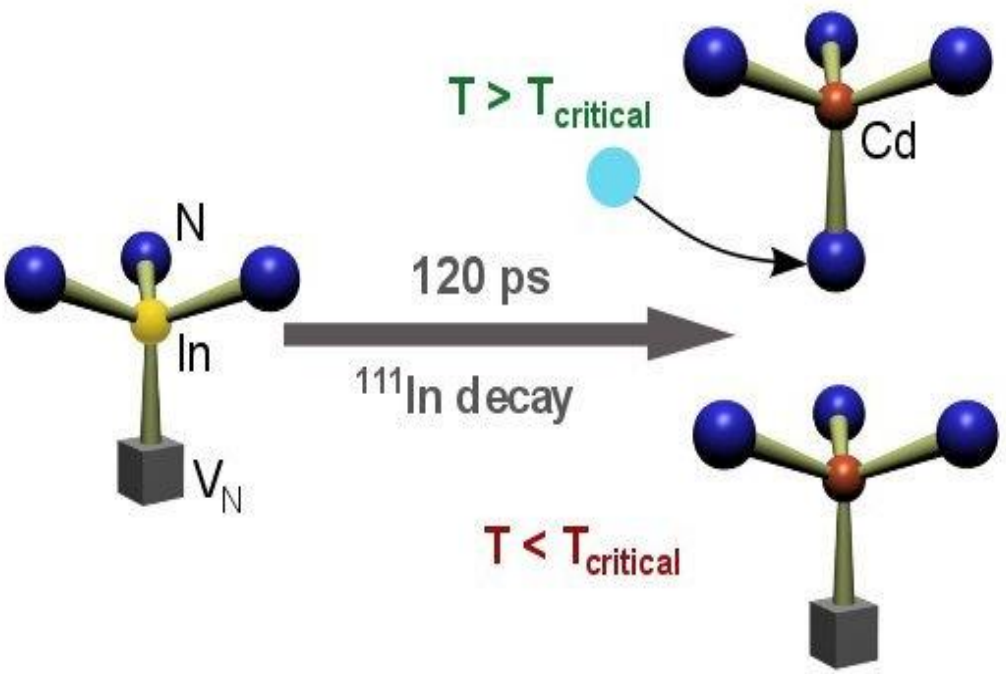
- Radio PL allows for the subtle chemical identification of luminescence through different decay chains.
- Has allowed for the identification of neutral and ionised donors [1, 2], complexed impurities [3], "double donor" centres [2, 4], and isoelectronic centres [5].

1. K. Johnston *et al* Phys Rev B **73** 165212 (2006).
2. K. Johnston *et al* Phys Rev B **83** 125205 (2011).
3. J Cullen *et al* Appl. Phys. Lett. **102** 192110 (2013)
4. J. Cullen et al Phys Rev B **87** 165202 (2013)
5. J. Cullen et al J. Appl Phys (2013)

Defects and electronic effects in wide bandgap semiconductors

IS481





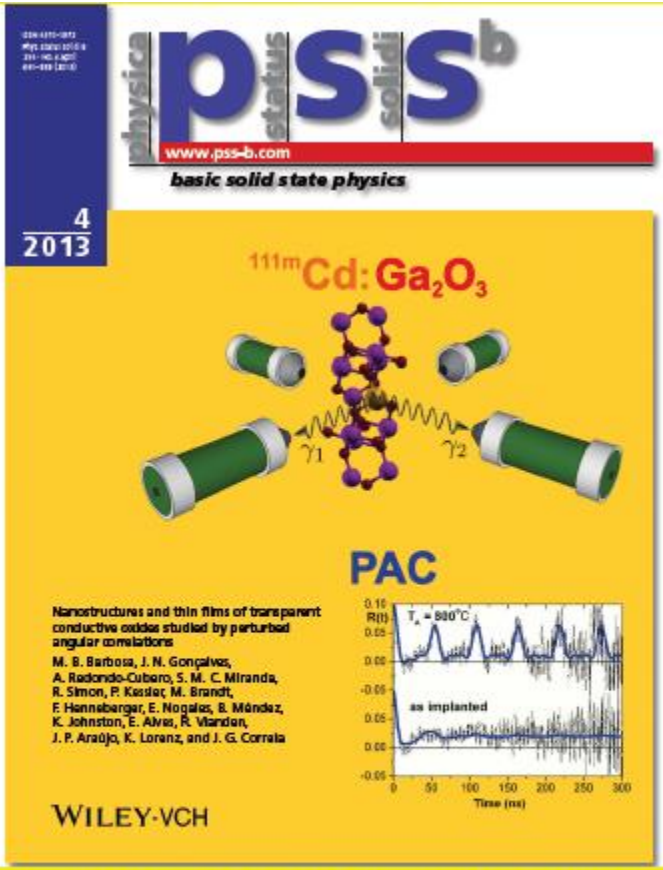
- The role of In in GaN and AlN has been studied by PAC:

→ A defect, probably V_N, is stabilized at the ^{111}In probe and is released at high temperatures after the decay to Cd.

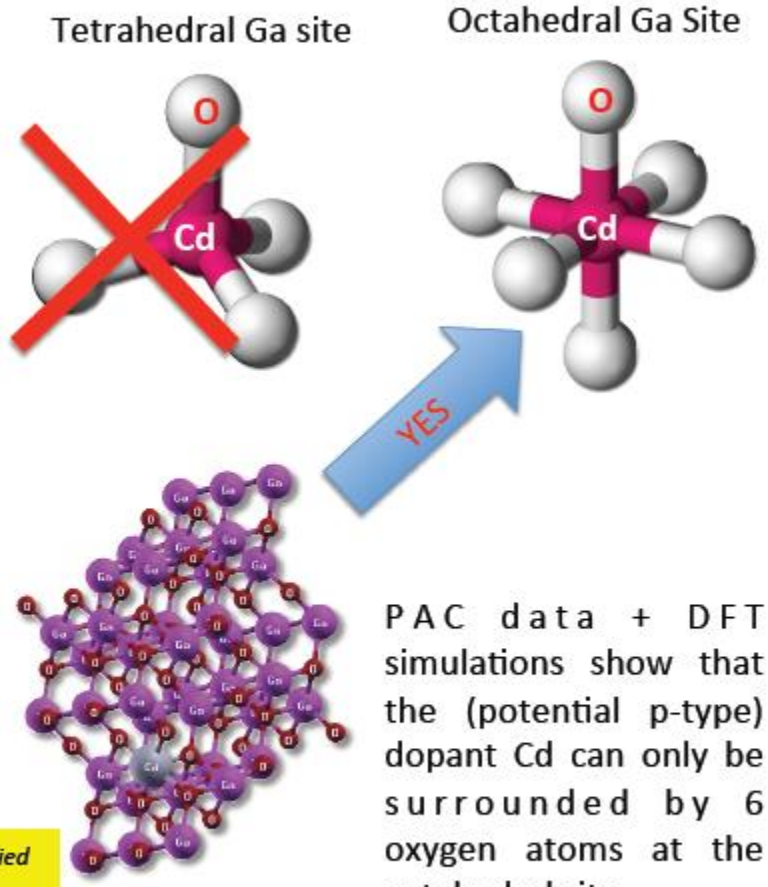
Kessler et al. HFI 197 (2010) 187; pss c 9 (2012) 1032

Electronic effects in Ga_2O_3

IS481



Nanostructures and thin films of transparent conductive oxides studied by perturbed angular correlations , M. B. Barbosa et al. Phys. Status Solidi B 250, No. 4, 801–808 (2013) DOI 10.1002/pssb.201200923



PAC data + DFT simulations show that the (potential p-type) dopant Cd can only be surrounded by 6 oxygen atoms at the octahedral site

4

→ Future work:
Studying electronic effects in Ga_2O_3 nanostructures and bluk crystals using γ–γ and e-γ PAC

Motivation .....

IS501

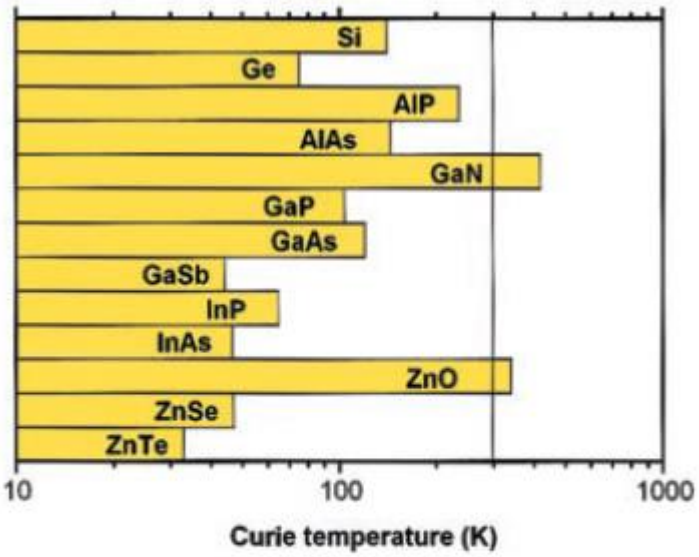


Fig. 3. Computed values of the Curie temperature T_C for various p-type semiconductors containing 5% of Mn and 3.5×10^{20} holes per cm^3.

Dietl *et al*, *Science* 287 (2000) 1019

Is it possible to create magnetic semiconductors that work at room temperature?

Such devices have been demonstrated at low temperatures but not yet in a range warm enough for spintronics applications.

Also motivation for IS432, IS450 and IS453

Fe: ZnO a ferromagnetic semiconductor? (no!)

IS501

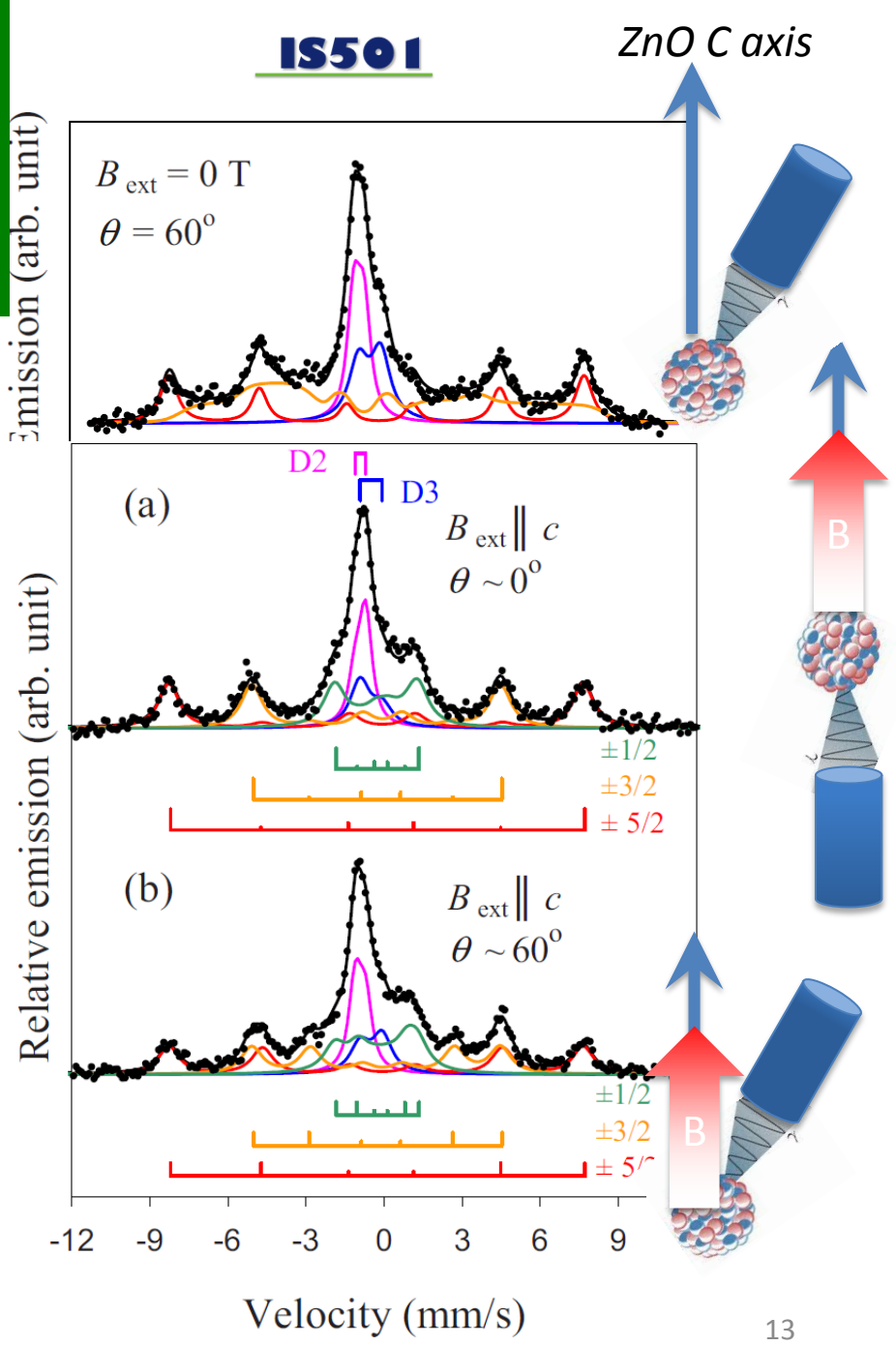
6 fold spectrum: characteristic of magnetic structure (at room temperature!!!).

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)

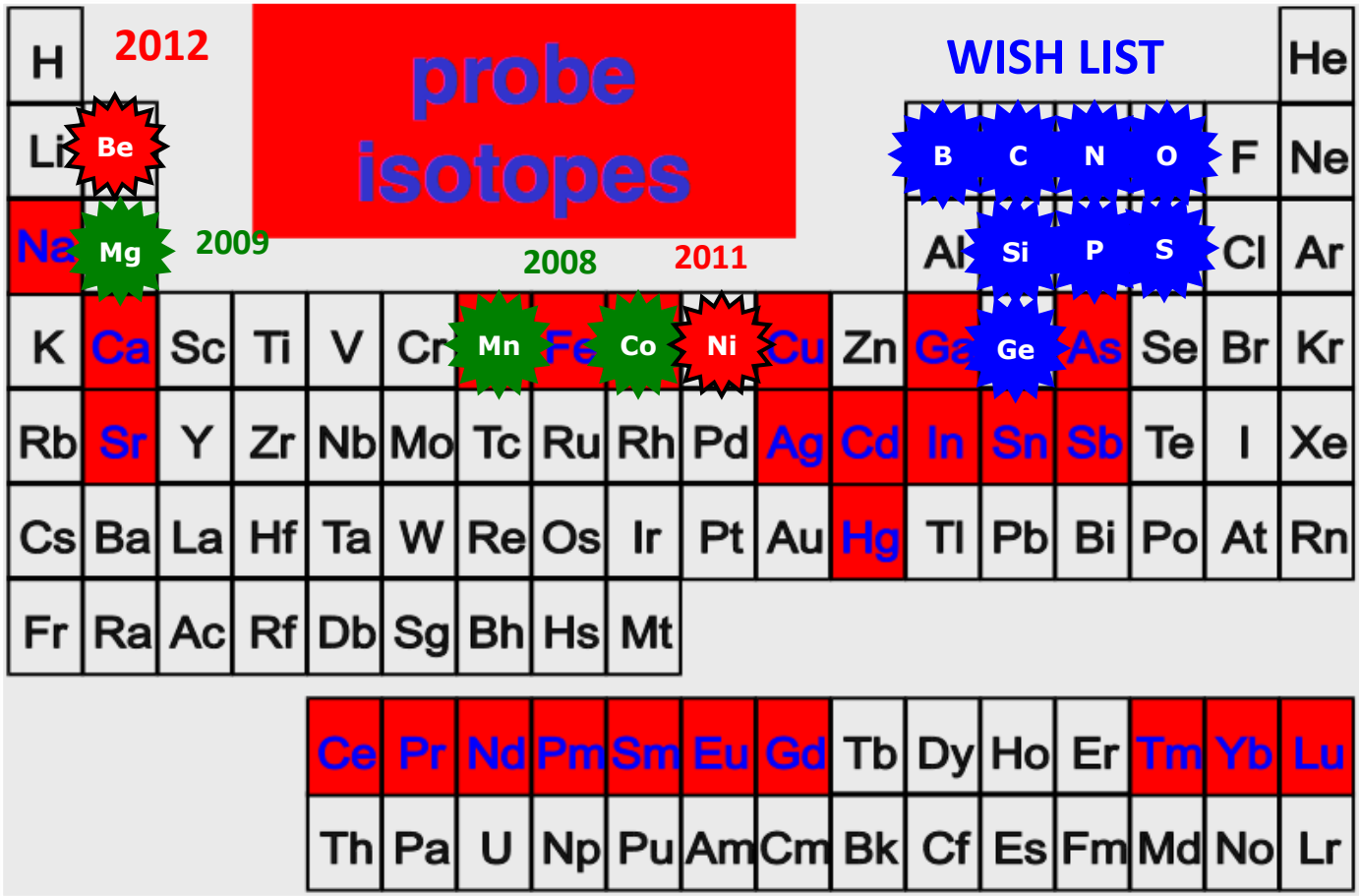
*After high-dose implantations, precipitates of Fe-III are formed. These form **clusters** yielding misleading information about the nature of magnetism in ZnO (as reported by many groups over the last number of years).*

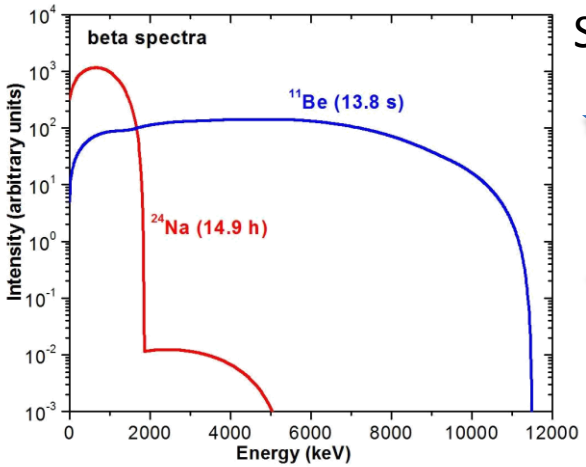
Gunnlaugsson *et al* APL **100** 042109 **(**2012)



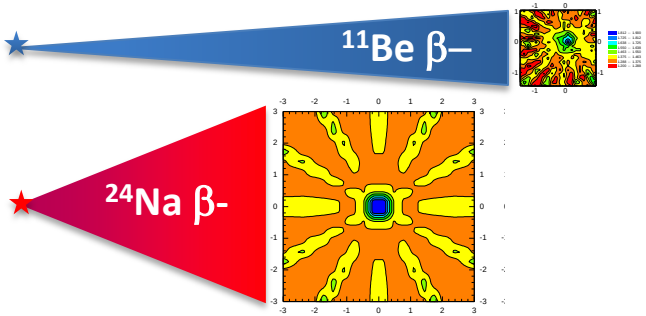
IS453

first ever done β⁻ EC patterns using ^{11}Be(14 s) in GaN

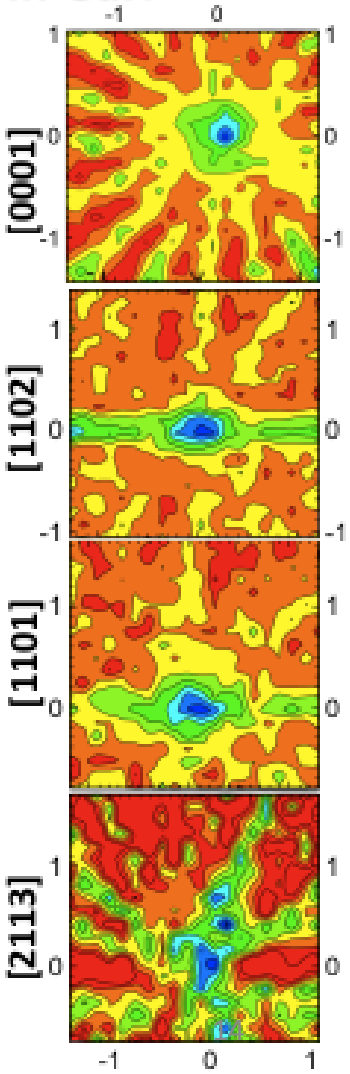




Source <-> detector : 60 cm



Source <-> detector : 30 cm



IBA 2013
21st International Conference on Ion Beam Analysis

Runner up in the "Young Researcher for Best Manuscript Competition" (sponsored by Elsevier BV) at the 21st International Conference on Ion Beam Analysis (IBA-21), Seattle, Washington, 23.-28.6.2013

Emission channeling studies on a challenging case of impurity lattice location: cation versus anion substitution in transition-metal doped GaN and ZnO

L.M.C. Pereira, U. Wahl, J.G. Correia, L.M. Amorim, D.J. Silva, S. Decoster, M.R. da Silva, K. Temst, and A. Vantomme

Award for Best Student Oral Presentation at the 17th International Conference on Radiation Effects in Insulators (REI-17), in Helsinki, Finland, 30.6.-5.7.2013

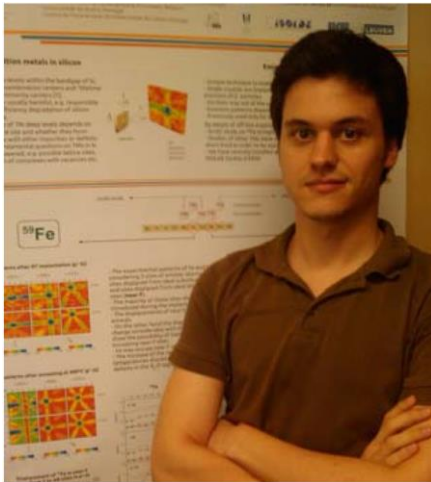
REI-17

attice sites of implanted Mg in the group-III nitrides

L. M. Amorim, U. Wahl, S. Decoster, L.M.C. Pereira, J.G. Correia, D.J. Silva, K. Temst and A. Vantomme

ICDS 27
Bologna, Italy, July 21-26, 2013

J.W. Corbett prize at the 27th International Conference on Defects in Semiconductors (ICDS-27), in Bologna, Italy, 21.-26.7.2013



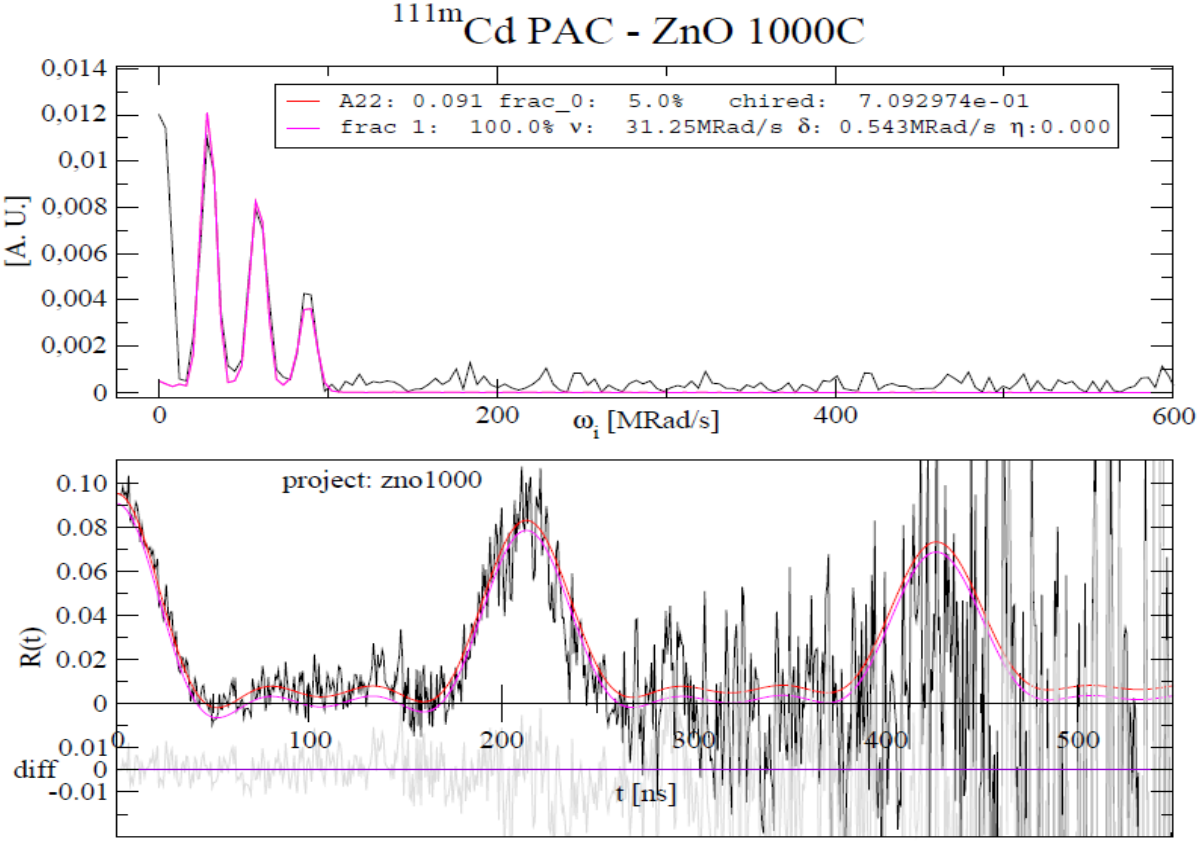
Influence of the doping on the lattice sites of Fe in Si

D.J. Silva, U. Wahl, J.G. Correia, and J.P. Araújo

Gauging Structural Aspects of ZnO nano-Crystal Growth Through X-ray Diffraction Studies and PAC

Use of ^{111m}Cd on ZnO nano size crystals , studying structural aspects

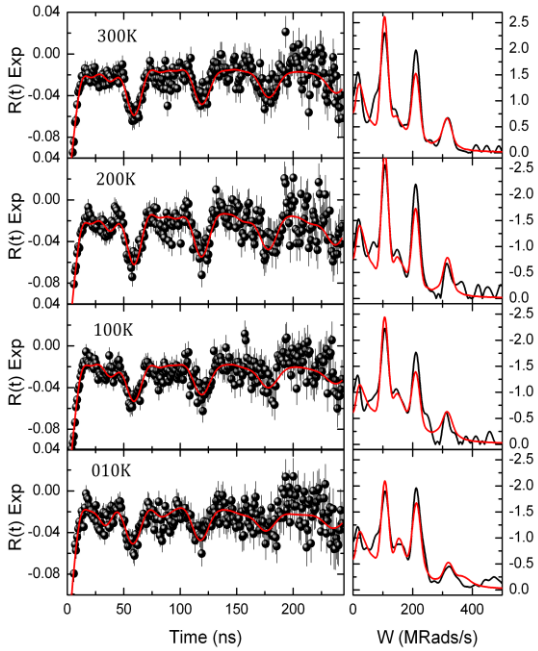
IS 544



Future projection : Growing ZnO nano-grains on folic acid template : biological applications , targeted drug delivery , use of ^{111m} Cd $^{+2}$ again for the PAC studies. Growing GaO(OH) nano grains OR GaO_2O_3 grains and doping with Tl+3 or Ru+3 Or In+3 ions for PAC analysis.

IS487 Study of Local Correlations of Magnetic and Multiferroic Compounds

Local PROBING of EFG and HMF in strongly correlated electron systems: spin, charge, orbital and lattice degrees of freedom

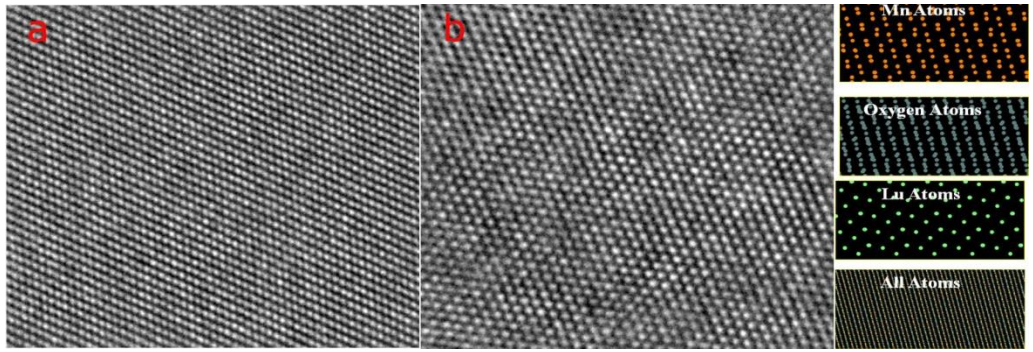


magnetic frustration reduction by local deformations in spin-ice systems DCr_2O_4, (D=Mg, Cd, Zn, Hg)

EFG and the electric polarization correlations . Multiferroic EFG/HMF relations

Confined and strained conditions (films&nanoP).

$LuMn_{0.96}O_{3\pm\delta}$ $LuMn_{1.08}O_3$



hexagonal manganites:

single crystal (YMnO3), magnetically frustrated $LuMn_xO3$.

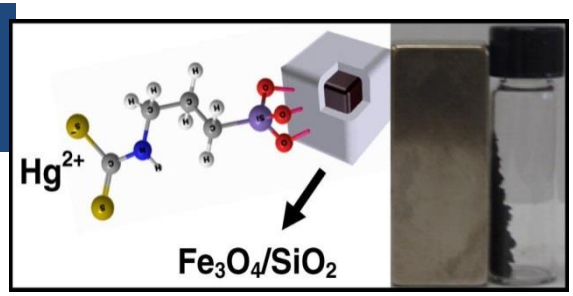
Inequivalent positions for ions, in contrast to perovskite structure and clustering effects

11,5 Shifts **isotopes:** ^{111m}Cd, ^{111}Ag, ^{117}Ag, ^{77}Br, ^{73}Br+^{73}Se, ^{199m}Hg

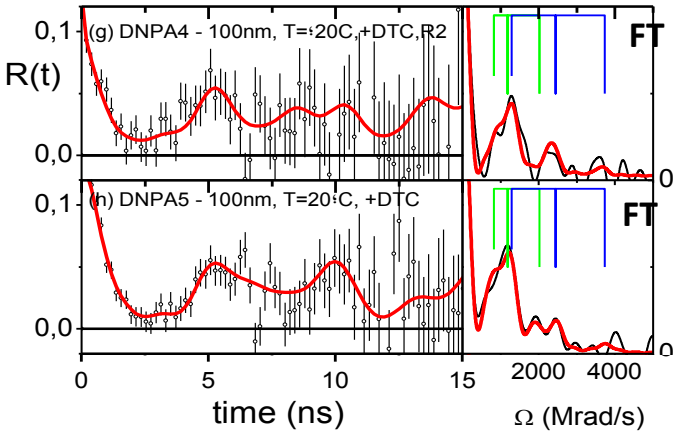
IS515

Radioactive probe studies of coordination modes of heavy metal ions from natural waters to functionalized magnetic nanoparticles

Local PROBING of EFG of local environment of ionic species (Hg^{2+}, Cd^{2+})



Two main electric field gradients in functionalized NP



EFG_1
ω_1= 1230 (20) Mrad/s
η_1= 0,16 (0,09)

EFG_2
ω_2= 629 (47) Mrad/s
η_2= 0,58 (0,02)

Results in NP different from the pure Hg-DTC compound, where Hg is coordinated to 4 sulphurs instead of the expected 2 on the nanoparticle surface.

Limited number of experiments
not yet significant statistics and systematic of results for control variables needed

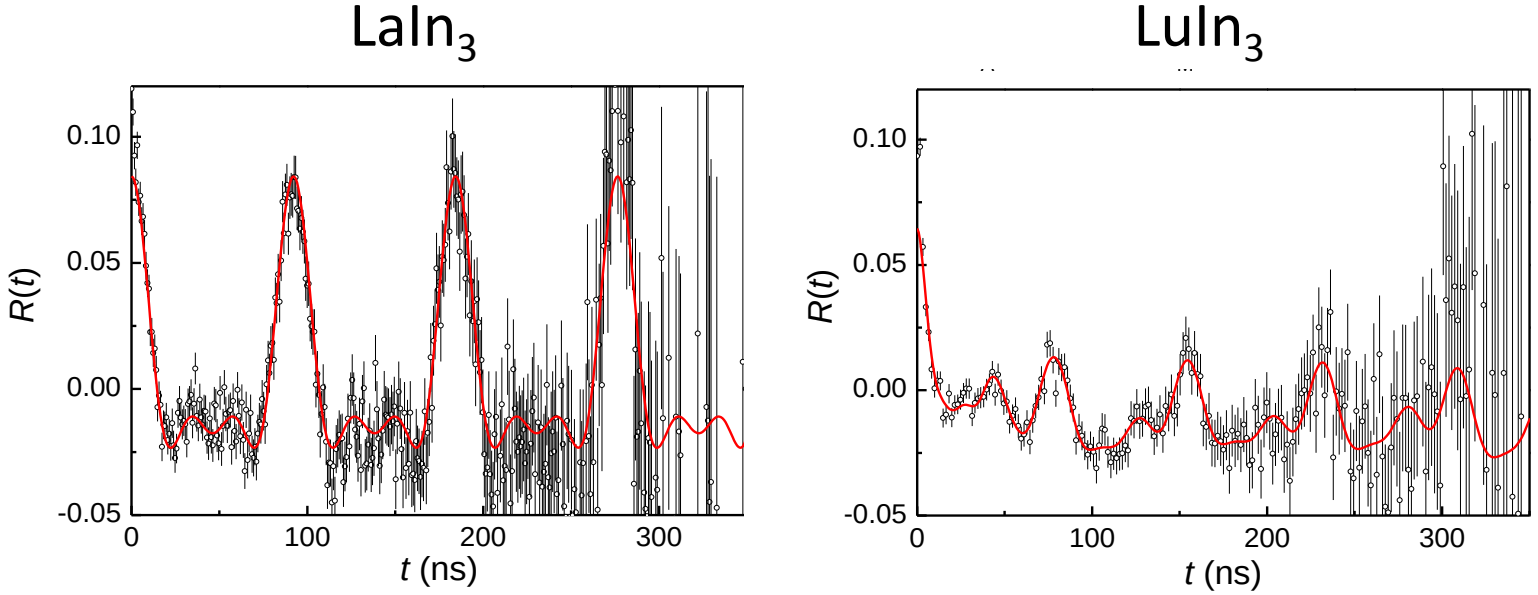
To complete the planned measurements program
-improvements on ion uptaking brought by different morphology/sizes, coverage and pH of the solutions, which determines the chemical speciation in the sample solution.
-study temperature dependence (0-30ºC), for signal quality/molecular motion in adsorbed water remaining
-Modelling studies of the obtained EFG

9 Shifts **isotopes:** ^{111m}Cd, ^{199m}Hg

^{111m}Cd in *R*In$_3$ (diffusion aspects using PAC)

IS514

- Hope: observe defects bound to Cd impurity at room temperature
- Result:

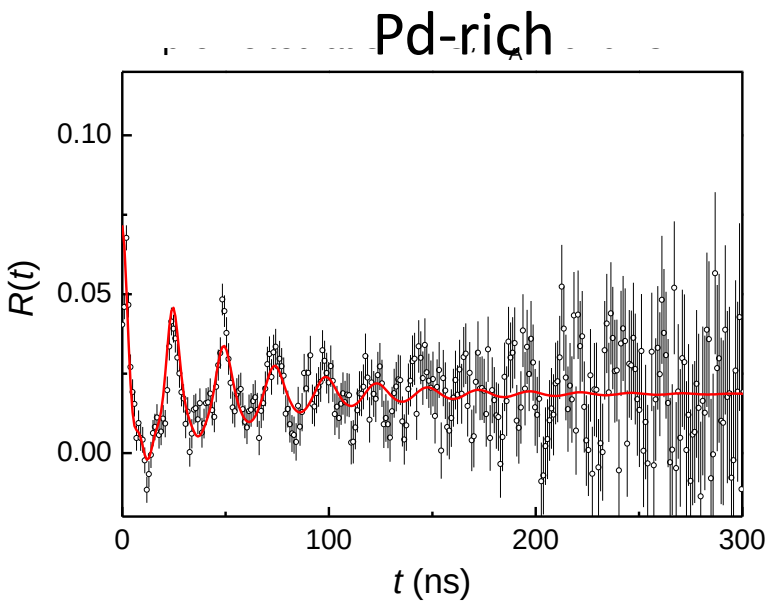


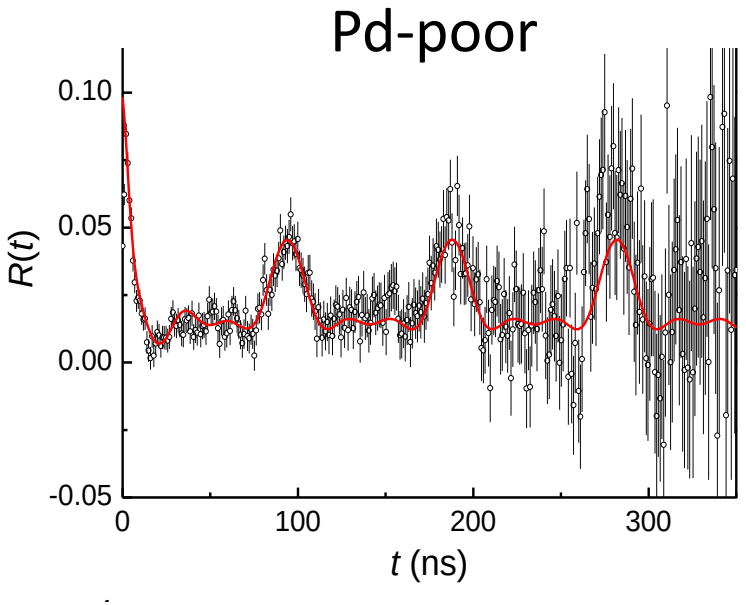
Same signals as observed using ^{111}In PAC ➔ no bound defects observed, → binding energy too low(?)

^{111m}Cd PAC in Pd_3Ga_7

IS514

- Goal: measure quadrupole relaxation at elevated temperature to complement earlier ^{111}In measurements
- Result of room temperature test measurements:





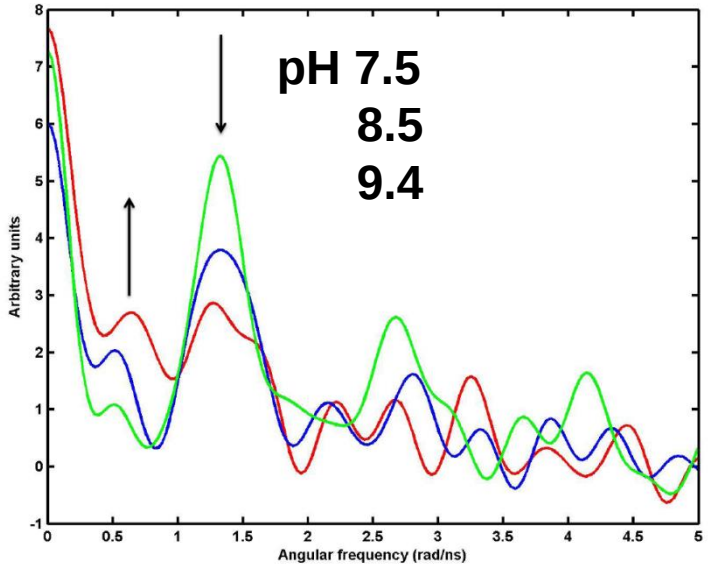
Signals differ from ^{111}In PAC results → improper sample preparation prior to implantation at ISOLDE → try again!

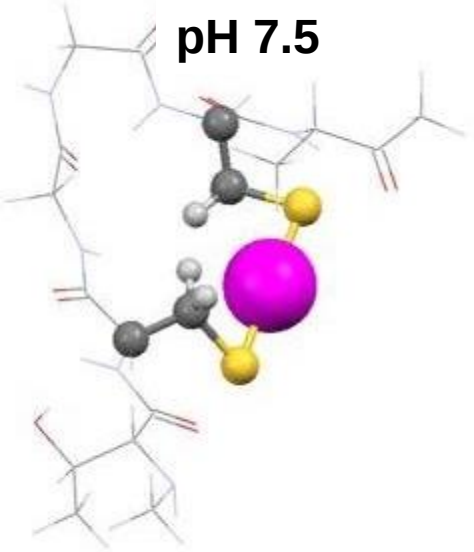
IS488

Metal ion transfer between proteins:

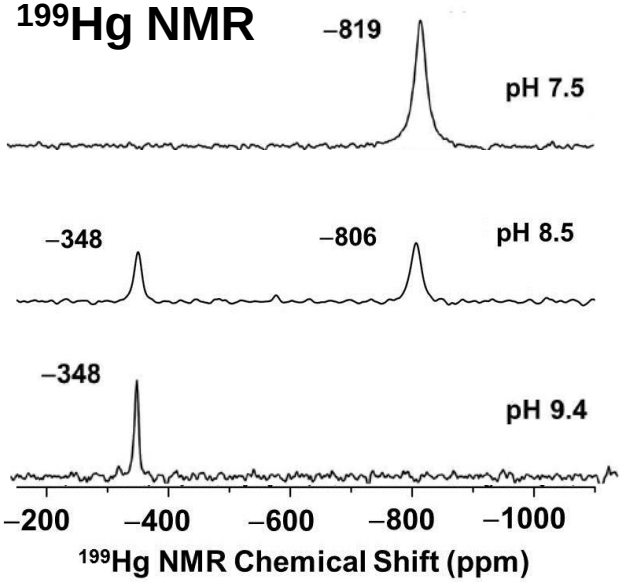
The Cu(I) binding protein HAH1

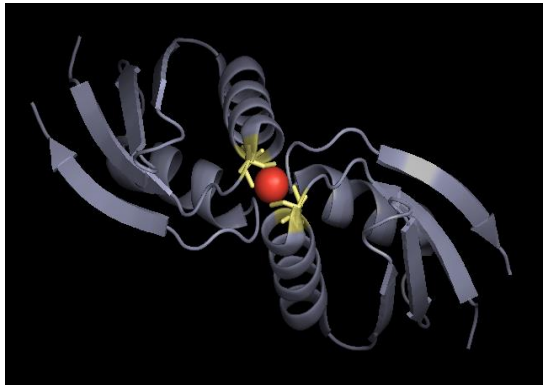
^{199m}Hg PAC

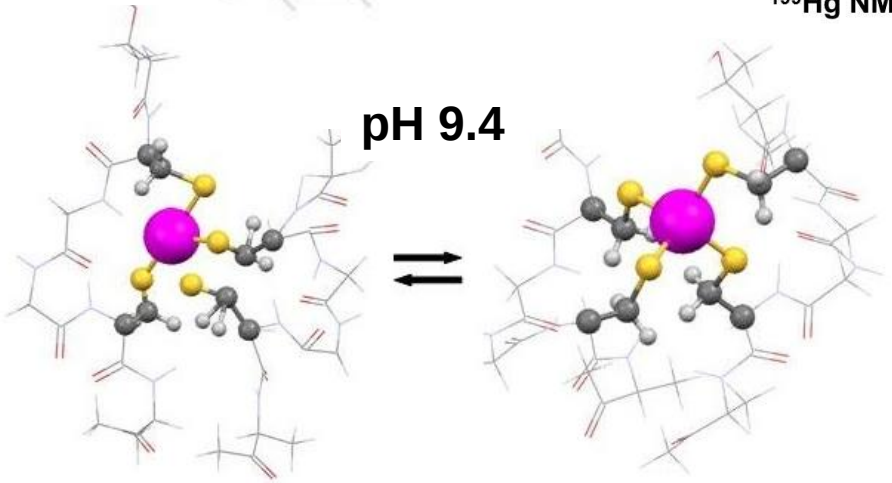




^{199}Hg NMR







Luczkowski *et al.*,
Chem. Eur. J., 2013, 19, 9042

IS528

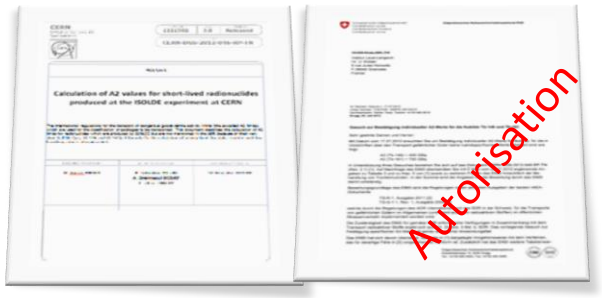
Significant improvement for shipping short-lived samples…

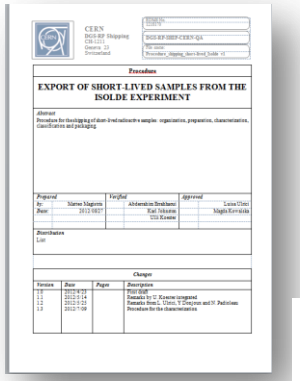
Spécificités : transports vie courte ISOLDE

Objectif 1 : Faire les transports Type A le plus rapidement possible

Valeurs A2 avec
U. Koester et K. Johnston

Procédure spéciale
En collaboration avec M. Magistris



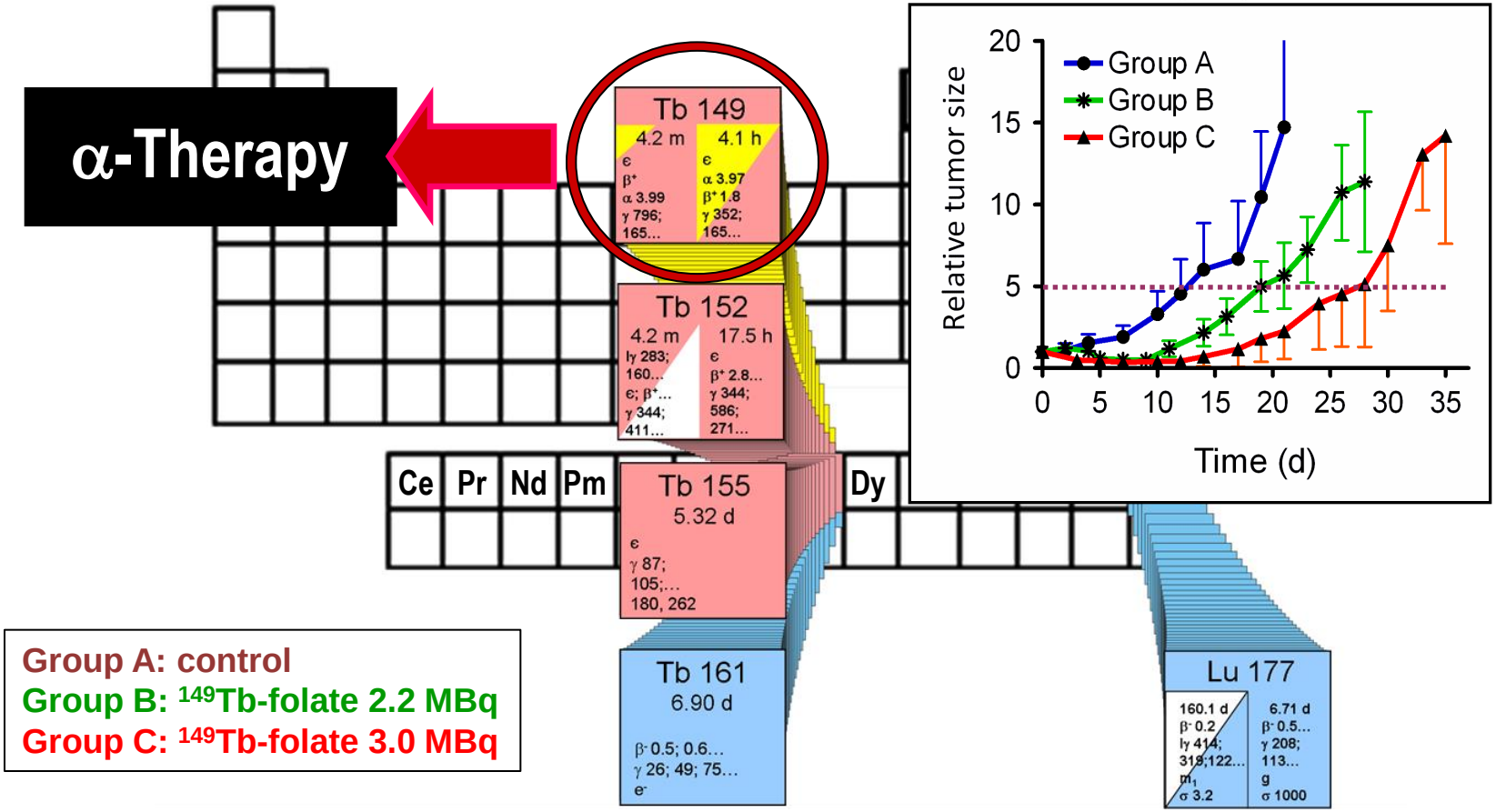


Slide thanks to Abderrahim Errahhaoui

IS528

Terbium-149: alpha-Emitter

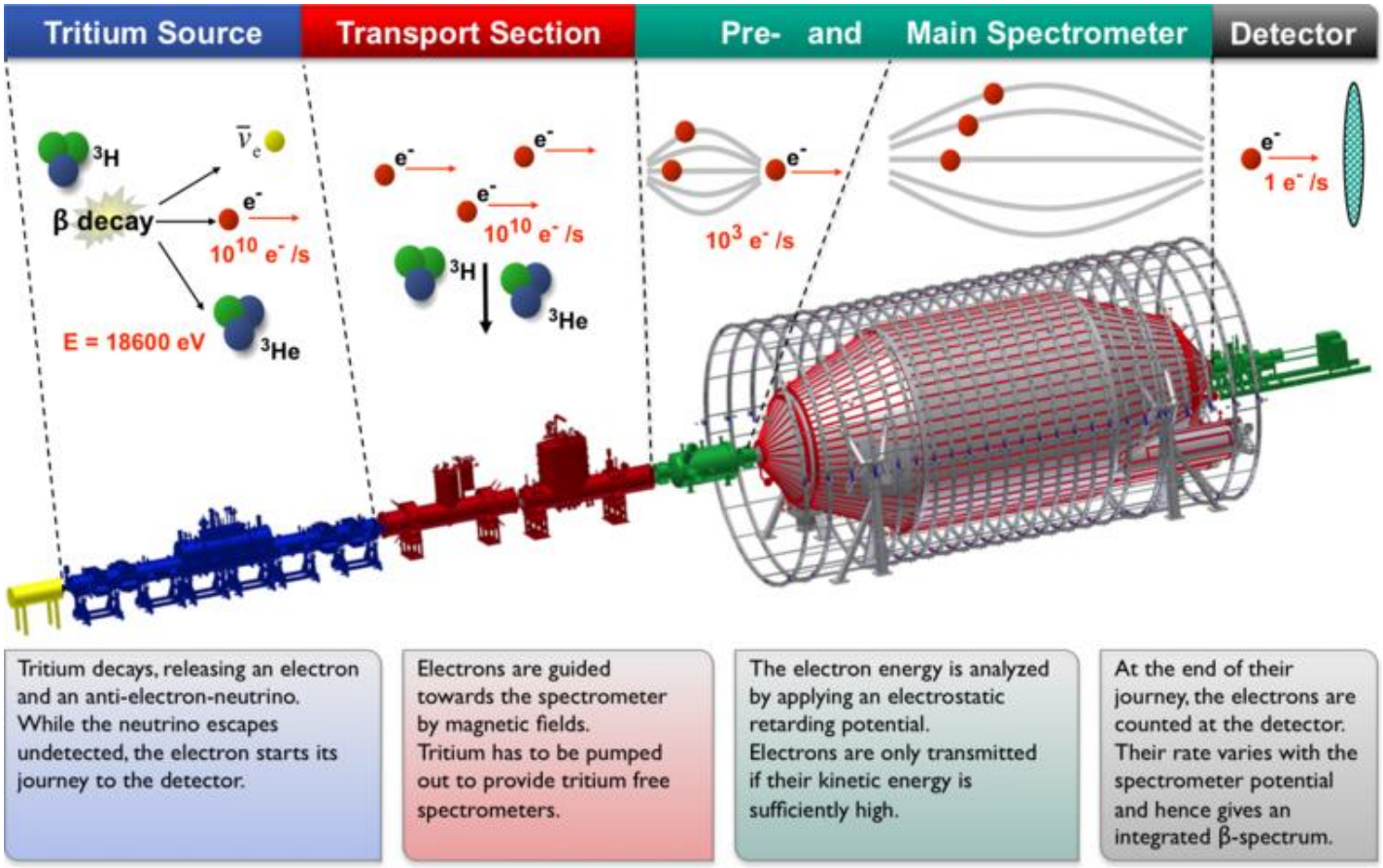
Folate Receptor Targeted α-Radionuclide Therapy



Group A: control
Group B: ^{149}Tb-folate 2.2 MBq
Group C: ^{149}Tb-folate 3.0 MBq

Müller et al. **2012**, J Nucl Med 53:1951.
Müller et al. **2013**, Pharmaceuticals, submitted

IS500



- For monitoring of KATRIN conversion electrons needed from decay of 83mKr T_1/2 = 1.8 h)
- 83mKr is generated by decay of 83Rb (T1/2 = 86 d), which is implanted into a solid platinum substrate (Ø 12 mm)
- ISOLDE produced 11 sources of 83Rb
- Bonn can now produce more reliable sources.

(IS533 similar principle)

Isotope	yield (/uC)	target – ion source	Shifts (8h)
IS432/IS450			
^{52}Mn	5.10^{7}	Nb foil RILIS	2
^{56}Co	10^{6}	YO/ZrO (VADIS)	3
IS481			
^{111m}Cd	10^{8}	Molten Sn / plasma	4
^{115}Ag/^{115}Cd /^{115}In	10^{8}	UC2, Ag RILIS with Nb or Ta ion source cavity to decrease In contamination	0.5
^{117}Ag/^{117}Cd /^{117}In	10^{8}	UC2, Ag RILIS with Nb or Ta ion source cavity to decrease In contamination	3.5
IS487			
^{111m}Cd	10^{8}	Molten Sn / plasma	7
^{199m}Hg	10^{8}	Pb / Plasma, run it at LOW temp, avoiding Tl	1
^{77}Br, ^{73}Br+^{73}Se	10^{8}	ZrO / plasma	1
IS488			
204mPb	1e8	UCx – RILIS	2
199mHg	1e8	Pb – VADIS	2
IS489			
^{29}Al	10^{8}	UC_2 – W surface	1
^{38}Cl	10^{8}	UC_2 – W surface	1
^{111}Ag ^{117}Ag/^{117}Cd	10^{8}	UC_2 - LIS	1
IS492			
^{77}Br	10^{8}	ZrO_2–HP	1
^{111}Ag ^{117}Ag/^{117}Cd	10^{8}	UC_2 - LIS	2

IS432/450 No recent results due to various technical problems : still relevant physics; RILIS Co scheme available…

IS481 Further work on Ga_2O_3. γ-γ, e-γ and β-γ studies … allows for unique information.

IS487 Continue work on magnetic frustration, links between EFG and polarisation , investigate multiferroic $ACrO_3$ compounds…

IS488 Pb preferred,: **challenging**. Test with synthetic protein.

IS489 Further commissioning of online chamber. Role of metallic contacts.

IS492 Further studies on Br in ZnO. Examine in more detail recently discovered Sn feature.

IS500			
^{83}Rb-83	500pA/ 1.6µA	Uc-Ta	1
IS501			
^{57}Mn	(2-3)×10^{8}	UCx, Mn RILIS	2
^{119}In	(2-3)×10^{8}	UCx, In RILIS	1
^{57}Co	9×10^{7}	ZrO_2/YtO_2, V/R(?)	1
IS514			
^{111m}Cd	2×10^{8}	Sn – HP (VADIS)	8
IS515			
^{111m}Cd	10^{8}	Molten Sn / plasma	2
^{199m}Hg	10^{8}	Pb / Plasma,	7
IS533			
^{83}Rb		UC-W / UC-Ta	6
IS544			
111mCd	5e8 µC	Molten Sn / plasma	2

IS500 Contingency shift in case problems at Bonn.

IS501 Co available with RILIS…. Complete programme on oxides, location of In in oxides.

IS514 Previous results failed due to problems with sample preparation. Now resolved, experiments to be repeated.

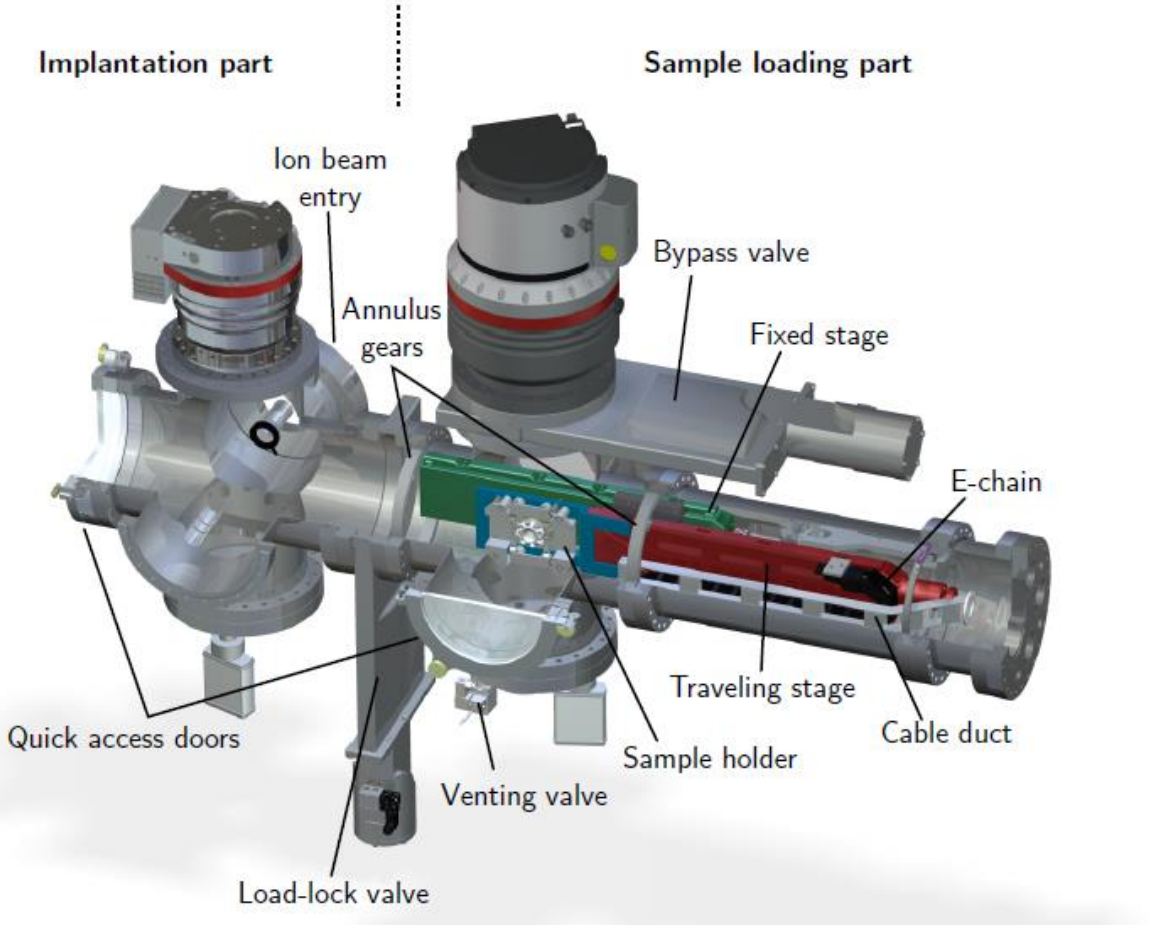
IS515 Understanding Hg-coordination, temperature dependence.

IS533 No previous shifts taken due to problems at ISOLDE. Still relevant

IS544 Further investigations on folic acid and cyclo

IS486: Addendum

- Request for extra shifts for commissioning the new general implantation chamber (due Summer 2014)
- Also: 2 shifts for development of online PAC using ^{19}O



isotope	yield (/uC)	target – ion source	Shifts (8h)
172-Lu	5e7	Ta or other (RILIS if possible)	1
149-Gd	5e7	Ta or other (RILIS if possible)	1
19-O	1e6	UCx VADIS	2

Summary

- 65 shifts to be kept for 13 experiments (of which 1 is for contingency only)
- 4 Shifts requested for IS486 to help complete their programme and commission the new GLM 2.0 chamber.

Publications & Theses

- 89 Publications published or accepted.
- 32 Theses (PhD, Masters either completed or about to be…)

Many thanks to collaborators for the slides

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