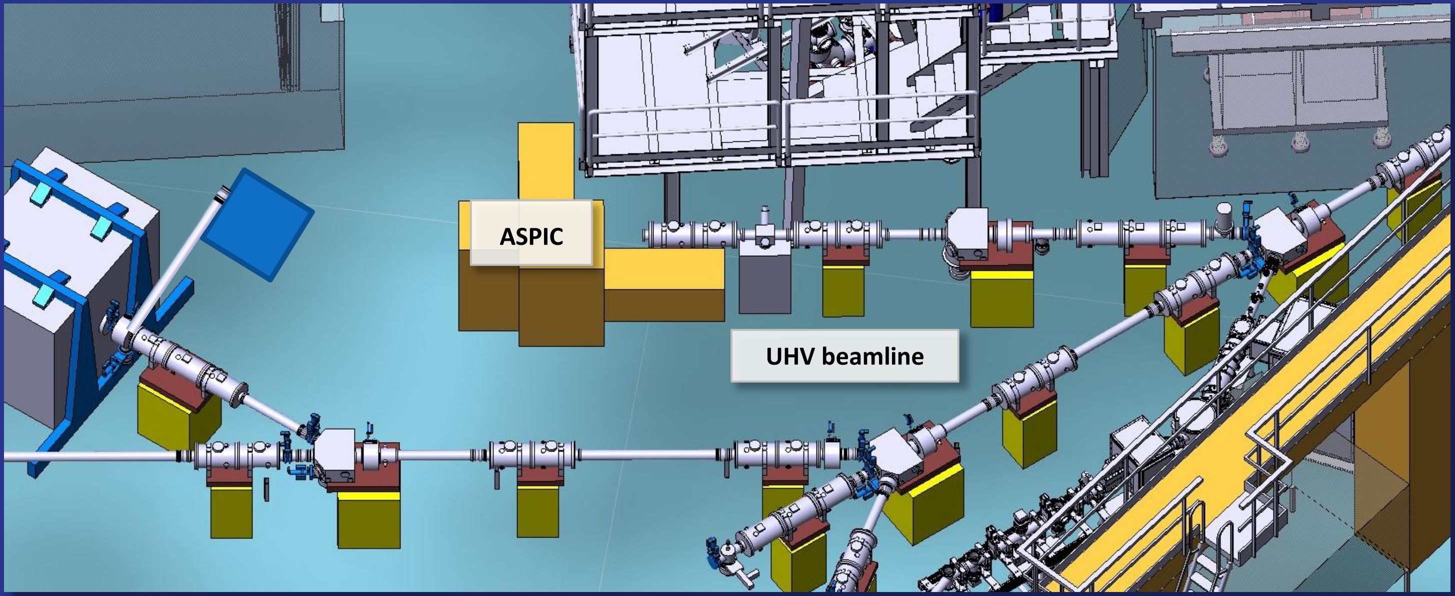


VITO project

Versatile Ion-polarized Techniques On-line at ISOLDE (former ASPIC UHV beamline)

M. Stachura on behalf of the VITO collaboration

ISCC committee, ISOLDE/CERN, 9 July 2013

Motivation

Goal of the project:

"Establishing a dedicated beamline for laser-induced nuclear orientation, which will open a wide range of possibilities for carrying out versatile and multidisciplinary experiments at ISOLDE."

Motivation:

- Versatile and multidisciplinary experiments (solid state physics, nuclear physics, biophysics….)
- β-asymmetry, β-NMR and PAC measurements (few mbar – 10^{-12} mbar)
- Ultra-high vacuum beamline (RB0) and ASPIC setup already existing
- ASPIC: partly maintained, ready for off-line experiments in 2013 (with ^{111}In)
- β-NMR setup from the tilted foil assembly (based on agreement with tilted foil collaboration)
- One open end station

Advantages:

- Upgrade of an existing setup
- Minimum budget required

ISOLDE

VITO Collaboration

- Motivation
- **Collaboration**
- Scientific goals
- Upgrade
- Timeline
- Budget
- Support

At ISOLDE:

Alexander Gottberg
EN-STI

Mark Bissell
COLLAPS

Magdalena Kowalska
ISOLDE PH coordinator

Karl Johnston
ISOLDE SSP coordinator

Ronald Garcia
COLLAPS, CRIS

Joao M. Correia
SSP

Zoe Lawson
KT

Solid state physics:

- **M. Deicher** - University of Saarland, Germany
- **Z. Salman** - PSI, Switzerland
- **V. Amaral** - Universitty of Aveiro, Portugal
- **J. Röder** - Aachen University, Germany
- **K. Potzger** - Dresden - Rossendorf, Germany
- **R. Kiefl** - The University of British Columbia, Canada
- **A. MacFarlane** - The University of British Columbia, Canada
- **L. Pereira** - IKS Leuven, Belgium

Nuclear physics:

- **G. Neyens** - IKS Leuven, Belgium
- **N. Severijns** - IKS Leuven, Belgium
- **D. Yordanov** - Max-Planck Institute Heidelberg, Germany

Biophysics:

- **L. Hemmingsen** - University of Copenhagen, Denmark
- **A. Jancso** - University of Szeged, Hungary

VITO Collaboration Meeting

Collaboration meeting
6th September 2013 (CERN)

M. Deicher - University of Saarland, GE

Z. Salman - PSI, CH

G. Neyens – IKS Leuven, BE

V. Amaral – University of Aveiro, PT

L. Hemmingsen – University of Copenhagen, DK

R. Neugart – University of Mainz, GE

L. Pereira – IKS Leuven, BE

D. Yordanov - Max-Planck Institute Heidelberg, GE

A. Gottberg – EN-STI, CERN, CH

J. Röder - Aachen University, GE

R. Garcia – IKS Leuven, BE

K. Potzger – Dresden – Rossendorf, GE

A. Fenta – University of Aveiro, PT

M. Bissell – IKS, Leuven, BE

K. Johnston – University of Saarland, GE

M. Stachura – PH, CERN, CH

Scientific Program

Letter of Interest to the INTC Committee

INTC-O-017

Spokesperson(s): M.Deicher and M. Stachura

2.1.1 Surface mediated magnetism in metal-oxide semiconductors

M. Deicher, K. Johnston, J. Lehnert, Th. Wichert, H. Wolf

2.1.2 Interaction and dynamics of add-atoms with 2-dimentional structures

(PAC studies of mono- and low-number of stacking surfaces)

V. Amaral, A. Gottberg, J.G. Correia, K. Johnston and the IDADS collaboration

2.1.3 Solar Cells Studies with ASPIC and PAC

J. Röder, A. Gottberg, T. Beckers, M. Martin

2.1.4 Low energy β-NMR for studies on condensed matter

Z. Salman

2.2.1 Bio-β-NMR spectroscopy on liquid samples

L. Hemmingsen, M. Stachura, A. Gottberg, M. Kowalska, P.W. Thulstrup

2.2.2 β-decay studies of laser-polarized radioactive beams

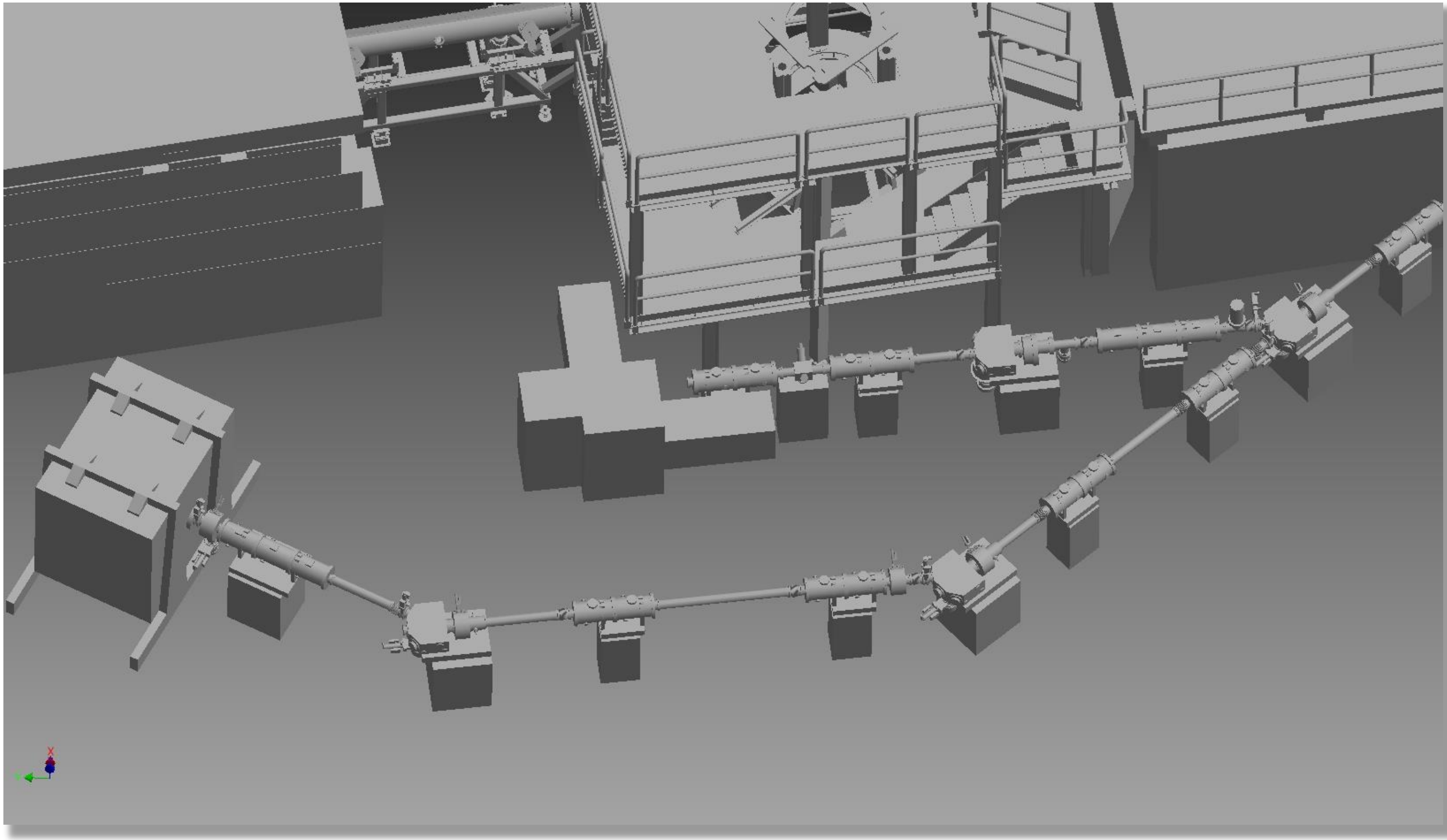
D. T. Yordanov for the proponents of INTC-I-090

2.2.3 V_{ud} from the β asymmetry parameter of mirror β transitions

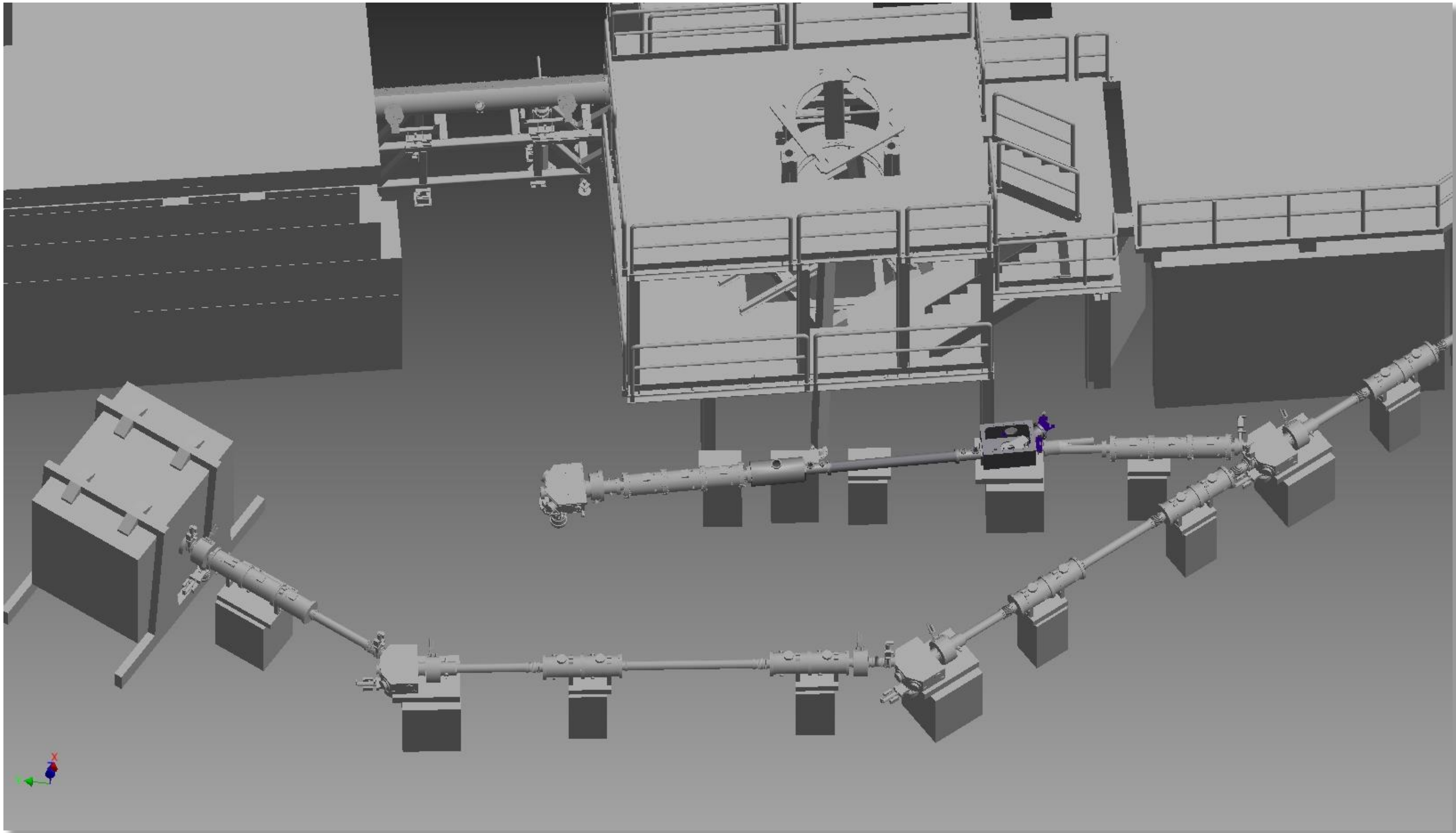
N. Severijns, G. Neyens, M. Bissell

Evaluated by the INTC committee!

Beamline Overview (existing)



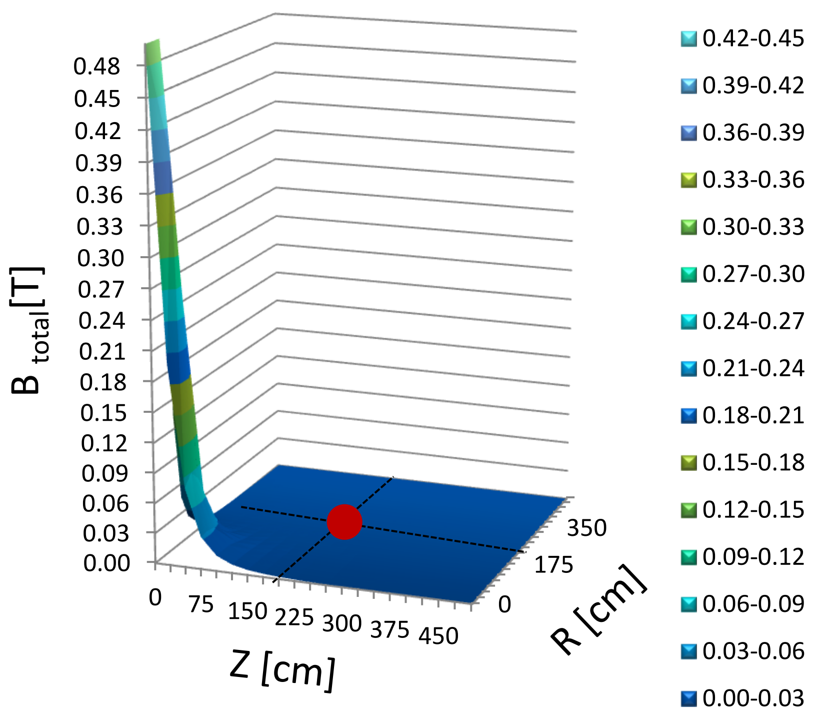
Beamline Upgrade (VITO, proposed)



Beamline Upgrade (VITO)

Possible influence from other setups:

- WITCH magnet



Based on WITCH 9T Stray Field

(provided by M. Breitenfeldt)

9T – max magnetic field

6T – magnetic field during experiments

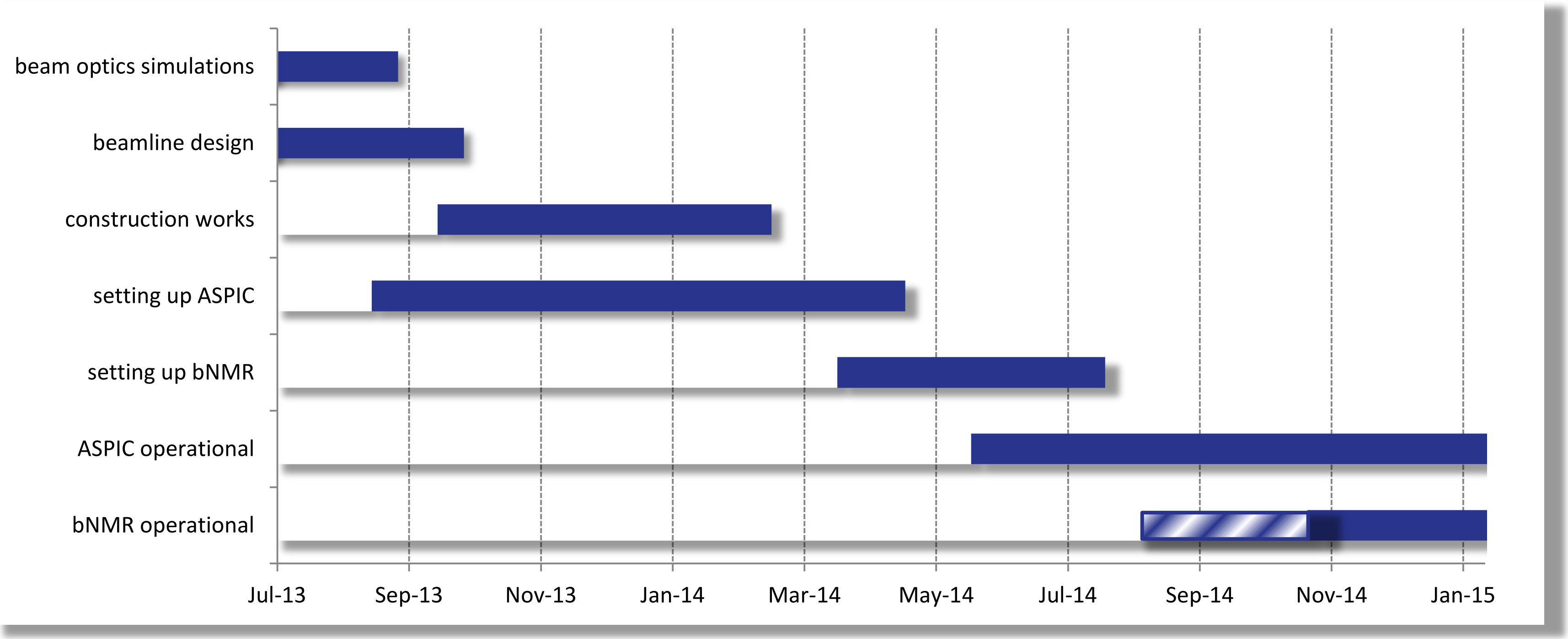
3T – when WITCH on standby

Possible influence on other setups:

- **Minimized influence** on HIE-ISOLDE, REX, WITCH, TAS and ISOLTRAP
- Access to the central beamline sustained

Timeline and Milestones

Timeline and Milestones:



Budget

Preliminary budget:

BMBF:	70 000 Euro
ISOLDE collaboration:	8 000 Euro
Biophysics:	2 500 Euro
Starting budget:	**80 000 Euro**

Optical pumping section from COLLAPS!

2 lasers (Nd-YAG and Ti-sapphire) from Saarbrucken!

Enough for the start-up of the experiment!

Grants:

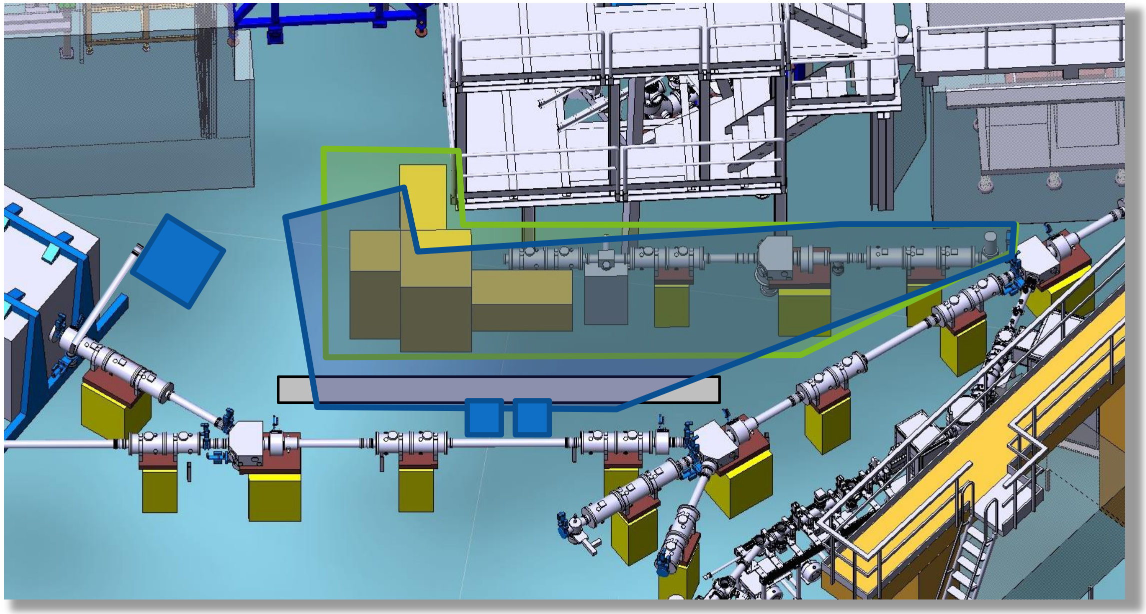
- Knowledge Transfer Found (CERN) – deadline in September 2013
- Carlsberg Foundation (Denmark) – deadline in October 2013
- Danish Research Council (Denmark) – deadline in November 2013
- Lundbeck Foundation (Denmark) – deadline in May 2014
- ERC grant – high grade, possible resubmission in 2014

Instruments, positions

Support

From the ISOLDE collaboration:

- Permission to re-locate the occupied space in the hall



From the physics group:

- Support during the beamline alignment and positioning (surveying team)
- Support in covering the initial VITO networking expenses (collaboration meeting in September)

Summary and Outlook

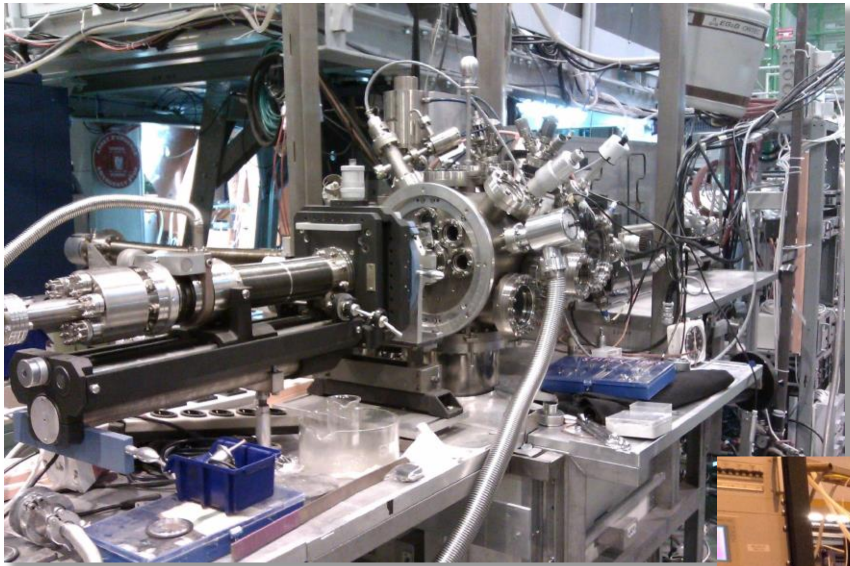
VITO project:

- Dedicated beamline with laser-induced spin-polarization at ISOLDE
- Three end stations: ASPIC, β-NMR and travelling experiments
- Versatile and multidisciplinary experiments (solid state physics, nuclear physics, biophysics)
- Modification of an existing UHV line, polarization assembly from COLLAPS collaboration
- Beam time request: ~ 70 shifts (20 different isotopes) over the period of 2-3 years, starting in summer 2014

Advantages:

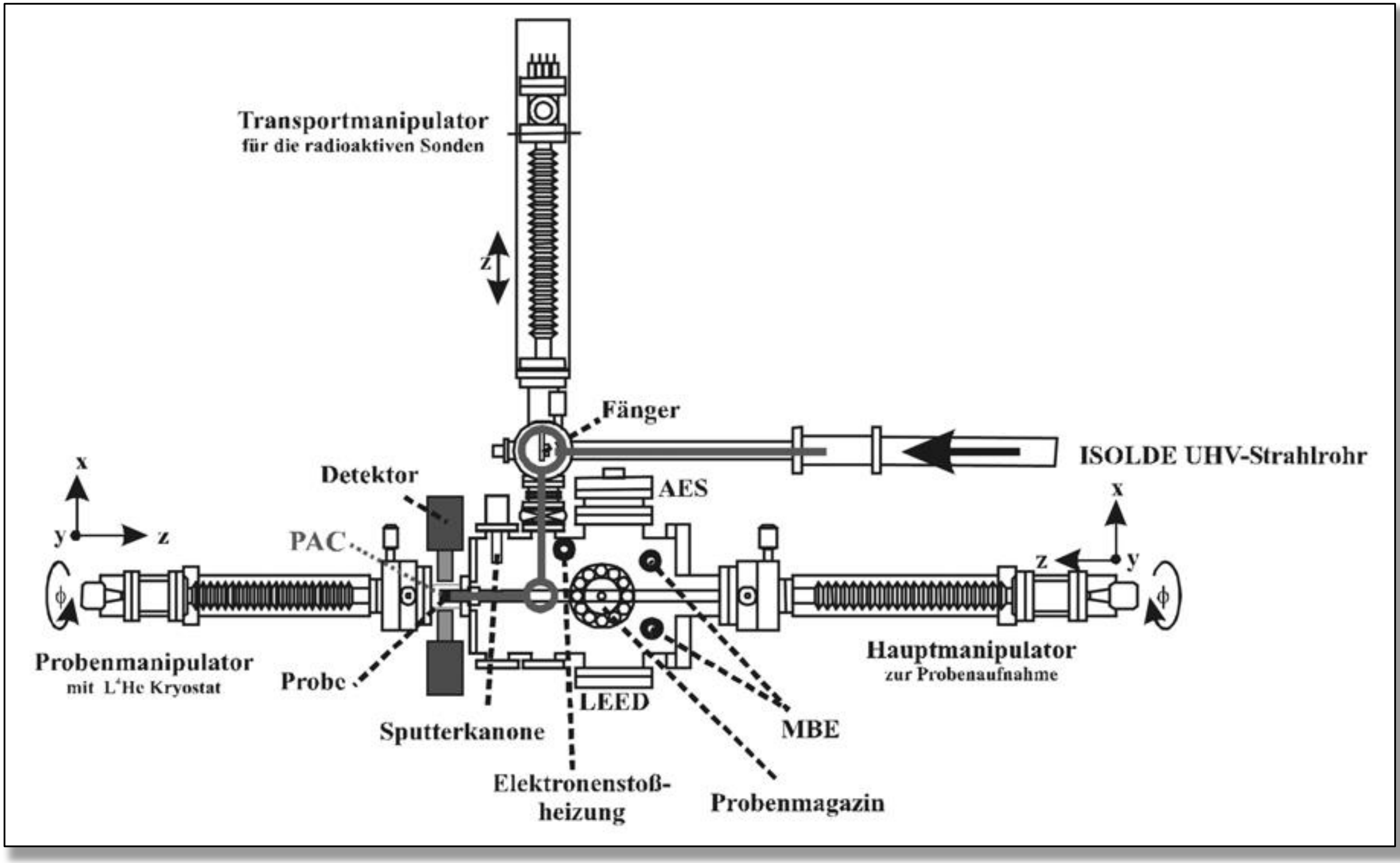
- Upgrade of an existing beamline
- ASPIC chamber maintained, restarted, ready for off-line experiments in 2013
- β-NMR setup from tilted foil assembly
- One open end station for travelling experiments

- ➢ No other competitive beamline at ISOLDE
- ➢ No other competitive beamline in the world
- ➢ ASPIC – unique experimental apparatus in the world
- ➢ β-NMR – multidisciplinary experiments (few mbar – 10^{-12} mbar; SSP, biophysics, nuclear physics)
- ➢ High prospective scientific impact



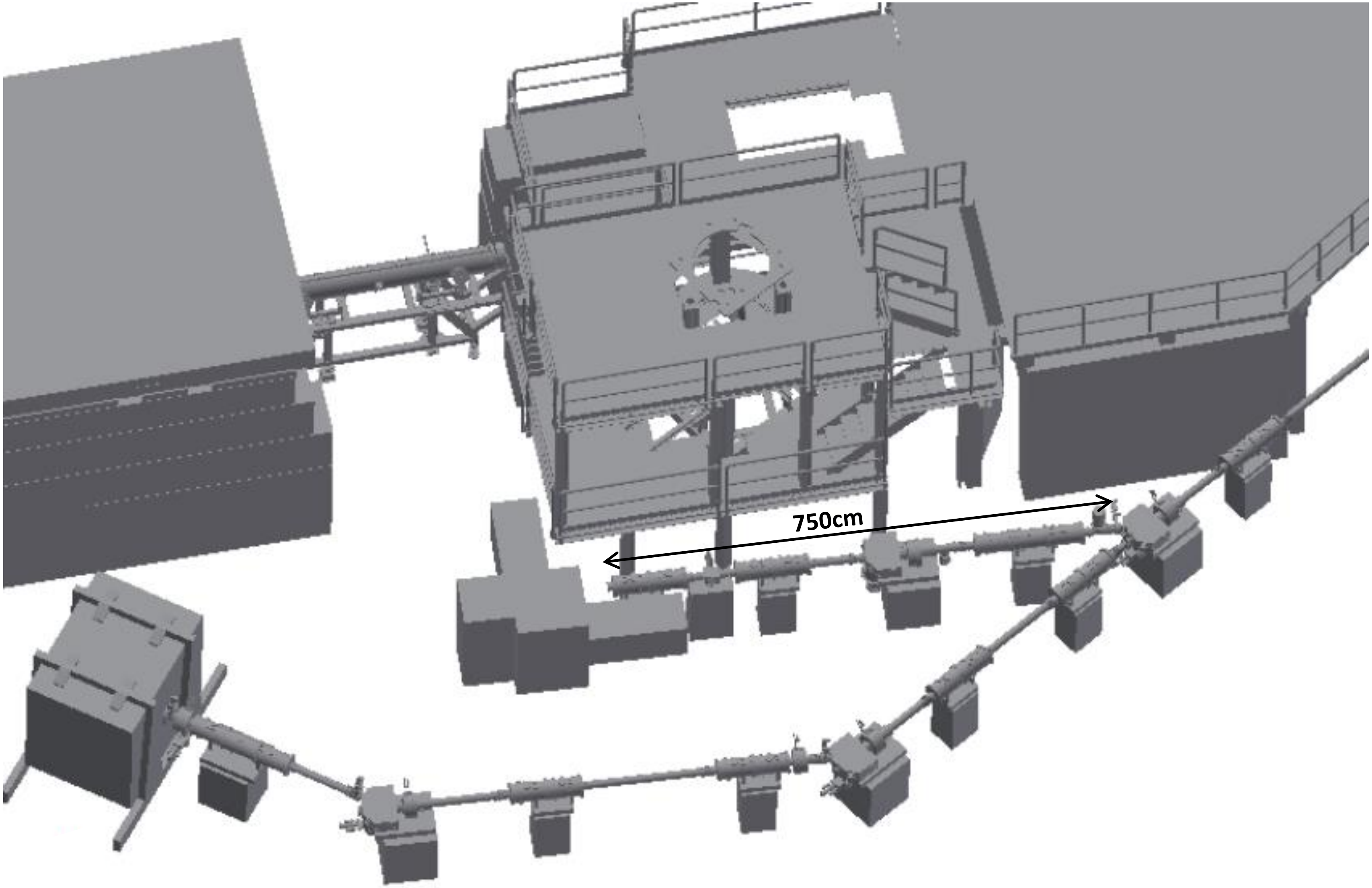
Thank you!

ASPIC Apparatus



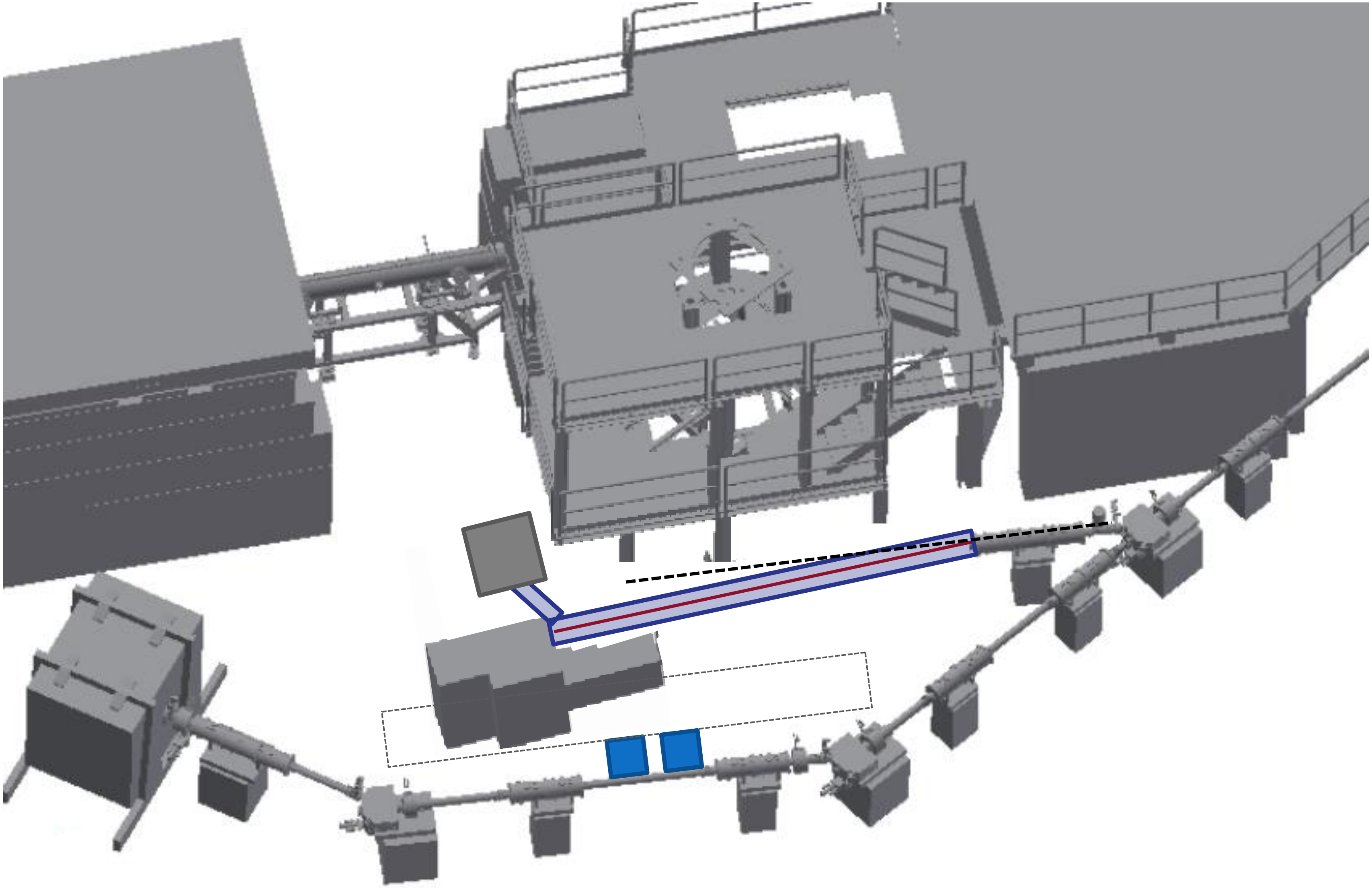
Beamline Overview (existing)

Motivation
Collaboration
Scientific goals
Upgrade
Timeline
Budget
Support
Outlook



ISOLDE

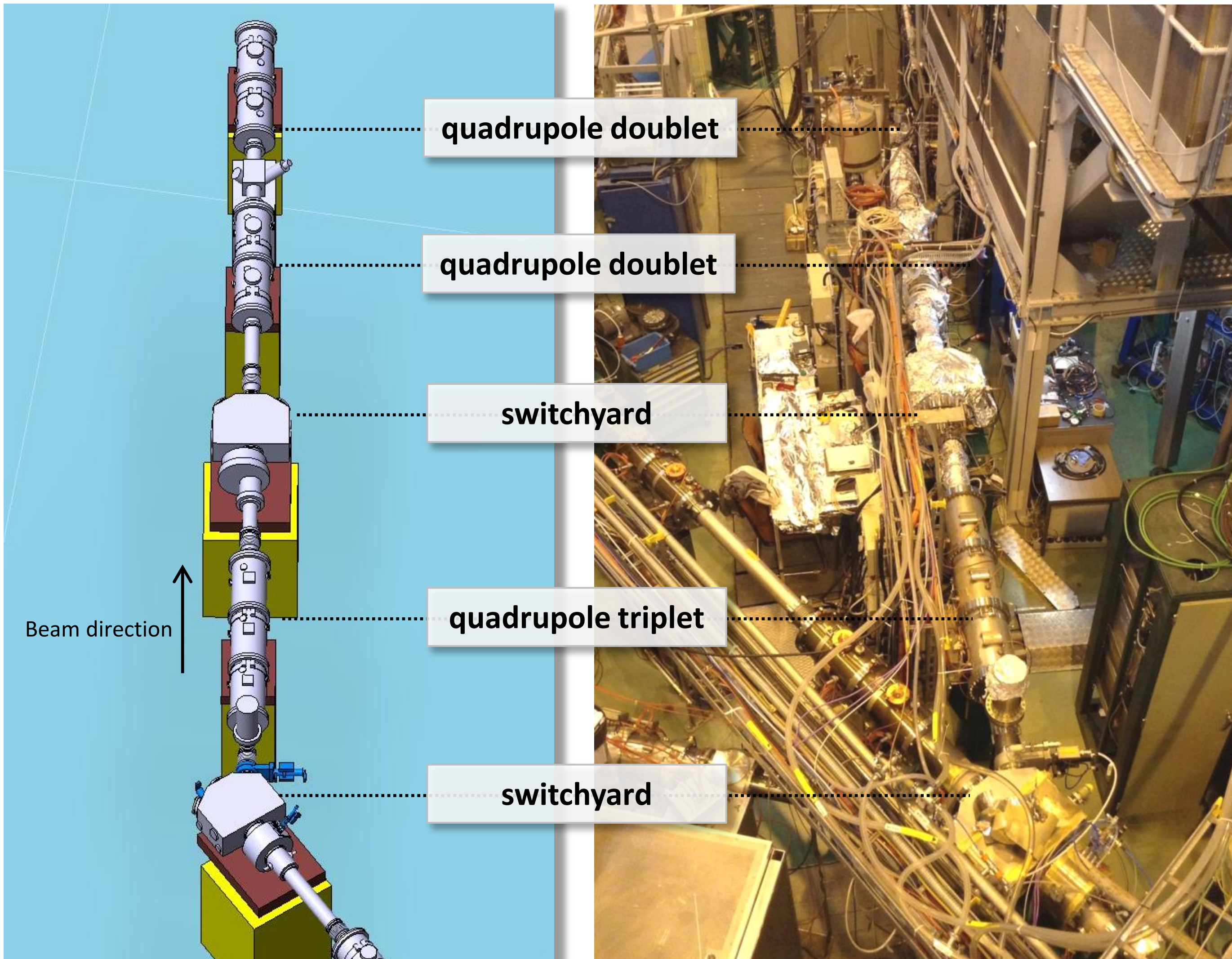
Beamline Upgrade (VITO, proposed)



Radioactivity

Mother	Decaying to	Life-time
^{8}Li	$^{8}Li \rightarrow {}^{8}Be$ (67 10^{-18} s) $\rightarrow {}^{4}He$	838 ms
^{11}Be	^{11}B	13.8 s
^{21}Na	^{21}Ne	22.5 s
^{33}Na	$^{33}Na \rightarrow {}^{33}Mg \rightarrow {}^{33}Al \rightarrow {}^{33}Si \rightarrow {}^{33}P$ (25d) $\rightarrow {}^{33}S$	8.2 s
^{23}Mg	^{23}Na	11.3 s
^{31}Mg	$^{31}Mg \rightarrow {}^{31}Al \rightarrow {}^{31}Si$ (2.6h) $\rightarrow {}^{31}P$	230 ms
^{33}Mg	$^{33}Mg \rightarrow {}^{33}Al \rightarrow {}^{33}Si \rightarrow {}^{33}P$ (25.3 d) $\rightarrow {}^{33}S$	90 ms
^{35}Ar	^{35}Cl	1.8 s
^{58}Cu	^{58}Ni	3.2 s
^{74}Cu	$^{74}Cu \rightarrow {}^{74}Zn \rightarrow {}^{74}Ca \rightarrow {}^{74}Ge \rightarrow {}^{33}S$	1.6 s
^{77m}Zn	$^{77m}Zn \rightarrow {}^{77}Ga \rightarrow {}^{77}Ge \rightarrow {}^{77}As$ (38.8 h) $\rightarrow {}^{77}Se$	1.05 s
^{73}Se	^{73}As	7.15 h
^{77}Br	^{77}Se	57 h
^{80m}Br	^{80}Br	4.4 h
^{111}In	^{111}Cd	2.8 d
^{111}Ag	^{111}Cd	7.5 d
^{111m}Cd	^{111}Cd	48 m
^{140}La	^{140}Ce	1.7 d
^{147}Gd	^{147}Eu	38 h
^{172}Lu	^{172}Yb	6.7 d
^{199m}Hg	^{199}Hg	42 m

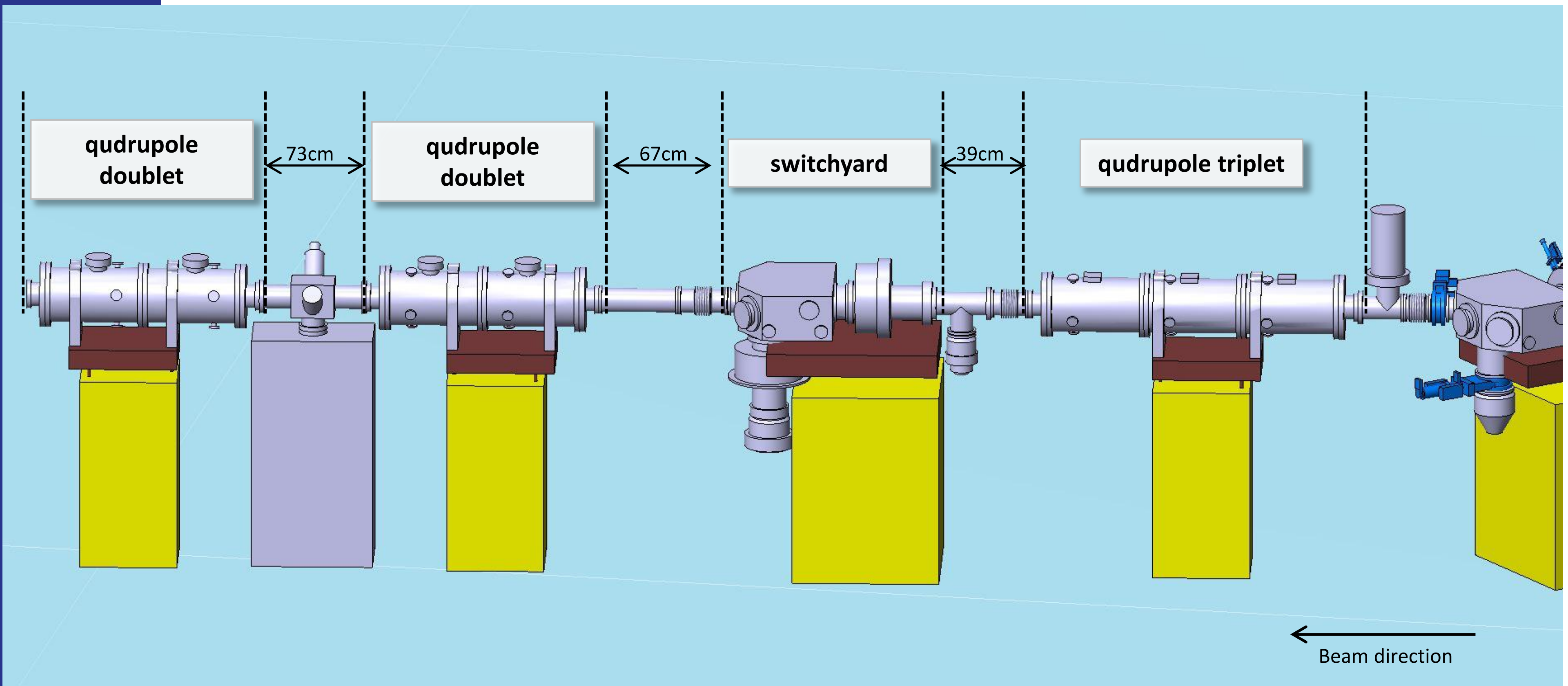
UHV Beamline



18

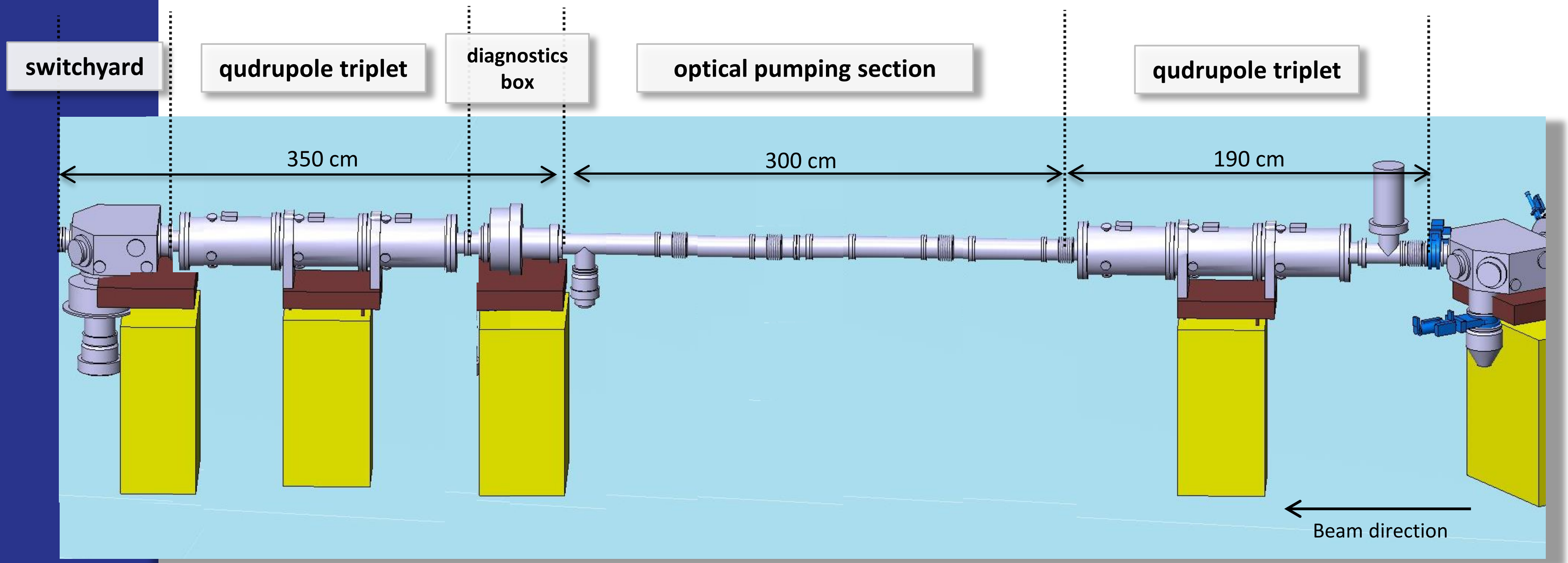
UHV Beamline

The existing UHV beamline



VITO Project

Suggested upgrade of the UHV beamline

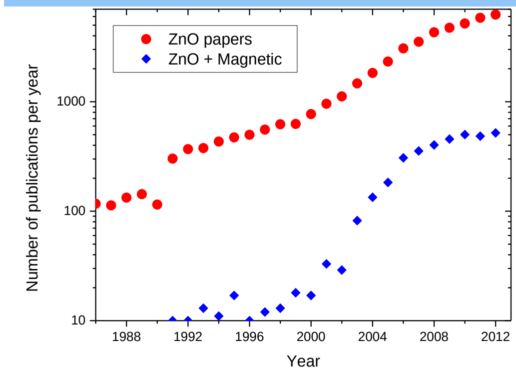


ASPIC End Station

2.1.1 Surface mediated magnetism in metal-oxide semiconductors

M. Deicher, K. Johnston, J. Lehnert, Th. Wichert, H. Wolf

Surface-related phenomena in dilute Magnetic semiconductors



Dietl Science (2000)

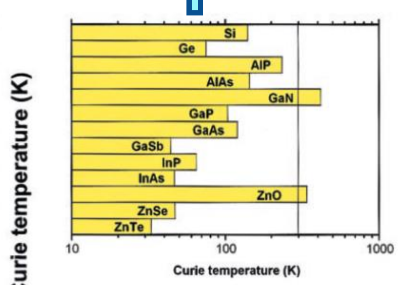


Fig. 3. Computed values of the Curie temperature T_C for various p-type semiconductors containing 5% of Mn and 3.5×10^{20} holes per cm^3.

Can surface effects affect magnetic behaviour in semiconductors?

Already know that magnetic behaviour can be mediated by defects (even non metallic…)

Recent reports discuss the possibility of surface defects critically affecting ferromagnetism in ZnO …

Use PAC + "soft landing" to probe different relevant configurations of impurities.

Possibility to extend studies to other materials: e.g. to investigate the recent observation of ferromagnetism in Cu-doped ZnSe…

Nature Nanotechnology **7**,792–797 (2012)

Estimated number of shifts: ^{111m}Cd (10 shifts)

ASPIC end station

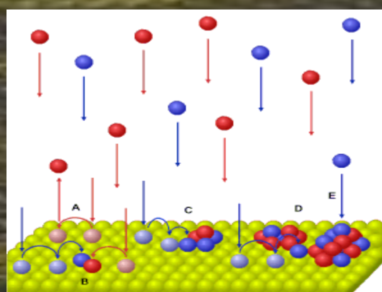
2.1.2 Interaction and dynamics of add-atoms with 2-dimentional structures
(PAC studies of mono- and low-number of stacking surfaces)

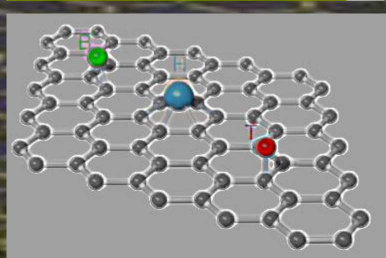
V. Amaral, A. Gottberg, J.G. Correia, K. Johnston and the IDADS collaboration

Interaction and Dynamics of Add-atoms with 2-Dimensional Structures

Hyperfine Techniques (PAC) + Add-atoms + ASPIC

a unique way to probe graphene (and more) at its 2D-scale





- **coordination mechanisms**
- **stability on top, within and under graphene layer**
- **catastrophic charge renormalization phenomena**
- **properties tunability by selective doping: new states (*Spin-Hall Effect and Spin-orbit coupling /Topological Insulators*)**
- **nucleation of artificial functional nanostructures**

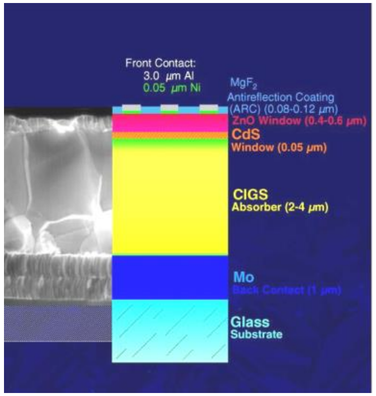
Understand Extreme Properties of Graphene and other 2D materials Energy and Sensor Technologies

GRAPHENE FLAGSHIP

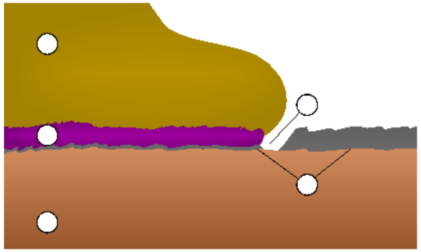
Estimated number of shifts: ^{77}Br/^{77}Se, ^{73}Se/^{73}As, ^{80m}Br/^{80}Br, ^{111m}Cd/^{111}Cd, ^{111}In/^{111}Cd, ^{140}La/^{140}Ce, ^{147}Gd/^{147}Eu, ^{172}Lu/^{172}Yb, ^{199m}Hg/^{199}Hg (18 shifts)

2.1.3 Solar Cells Studies with ASPIC and PAC

J. Röder, A. Gottberg, T. Beckers, M. Martin



- Study of interfaces and layers of solar cells like Cu(In,Ga)Se and muli-layer solar cells
- Third generation semiconductors: multi-layers of different types of semiconductors and their interaction
- Address aging effects of solar cells
- Surface investigations



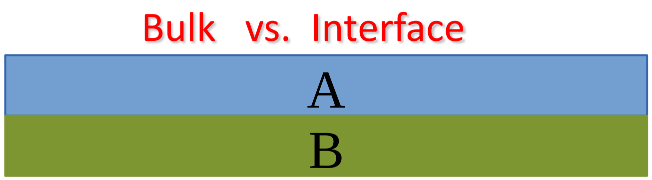
- Gold-Aluminium contacts used, e.g. in space devices and solar cells have problem of purple plague
- Study of the interface phase changes

Estimated number of shifts: ^{111}Ag, ^{111}In, ^{111m}Cd, ^{198m}Ag (10 shifts)

ASPIC End Station

2.1.4 Low energy β-NMR for studies on condensed matter

Z. Salman



What happens near and interface between two materials A and B?

- We go from 3D to 2D system
- Changes in magnetic, electronic and structural properties.

Questions:

- How/why do the properties change?
- What is the length scale of changes?
- Can we classify these changes?

Motivation:

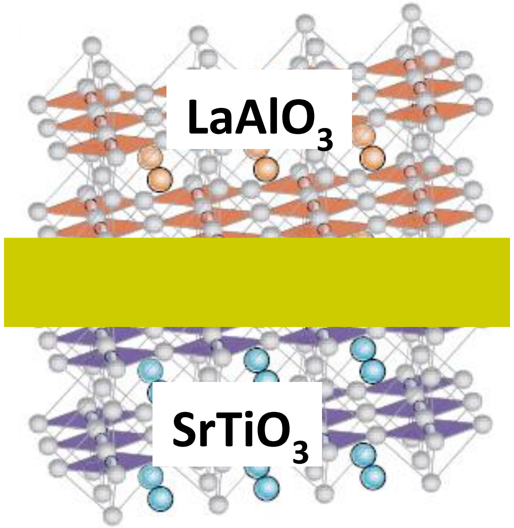
- Better understanding of both bulk and interface
- Application in devices.

Example:

Both $LaAlO_3$ and $SrTiO_3$ are insulating and non-magnetic.

The interface between them becomes

conducting/metallic and magnetic.



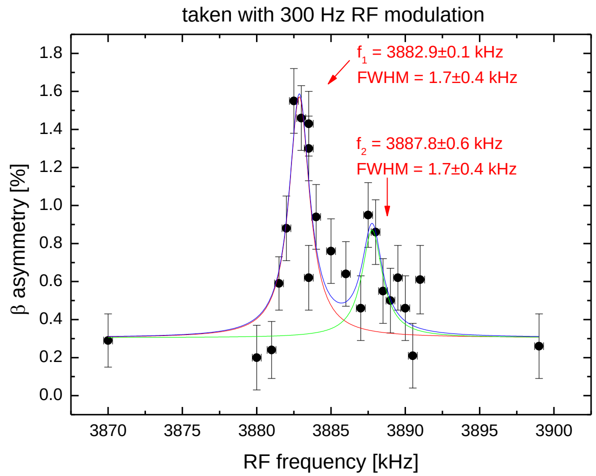
Estimated number of shifts: ^8Li, ^{11}Be, ^{15}O

β-NMR Spectroscopy End Station

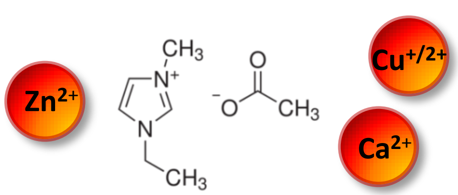
2.2.1 Bio-β-NMR spectroscopy on liquid samples

L. Hemmingsen, M. Stachura, A. Gottberg, M. Kowalska, P.W. Thulstrup

1. Proof of principle: $^{31}Mg^{2+}$ in ionic liquid (EMIM-Oac) – done!

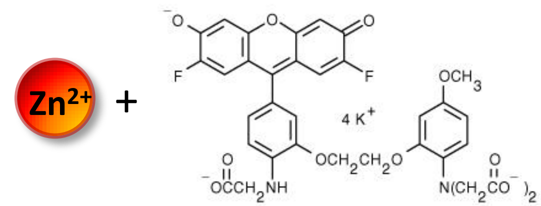


2. Other biologically essential metal ions in EMIM-OAc



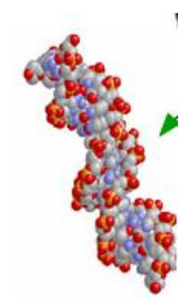
(EMIM-OAc = solvent)

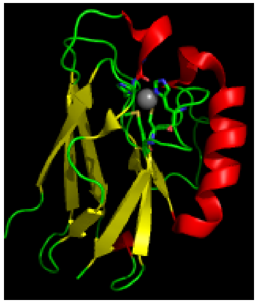
3. Observing metal ion binding to a molecule (using high affinity fluorophores) in ionic liquid solution

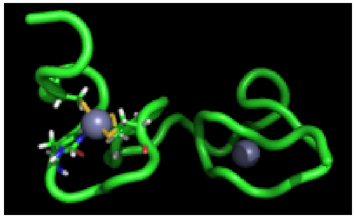


For example FluoZin™-3 from Invitrogen
http://products.invitrogen.com/ivgn/product/F24194

4. Perspectives: Metalloproteins and nucleic acids in aqueous solution





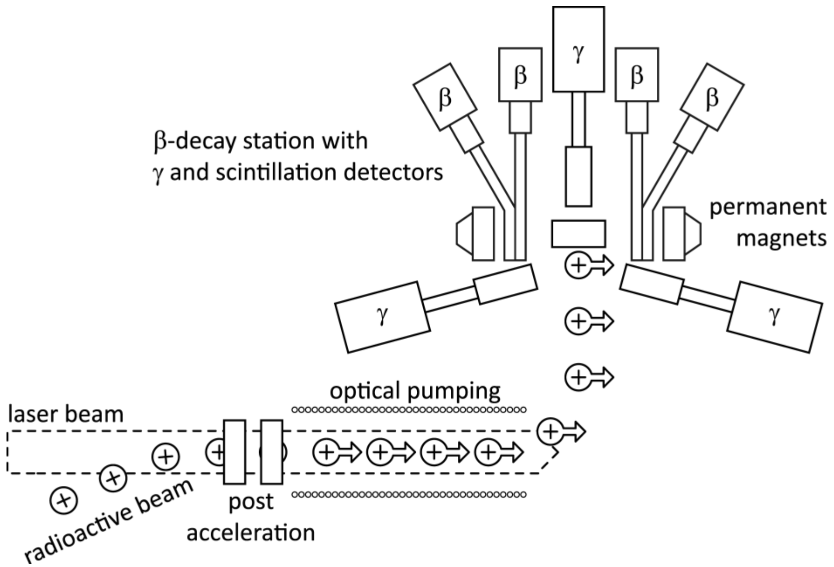


Estimated number of shifts: ^{31}Mg, Ca, ^{58}Cu, ^{74}Cu, ^{77m}Zn (30 shifts)

β-NMR Spectroscopy End Station

2.2.2 β-decay studies of laser-polarized radioactive beams

D. T. Yordanov for the proponents of INTC-I-090



- Alternative geometry for the optical pumping → no need of a 90˚ turn of the polarization direction
- No need of the bending magnetic field
- Higher degree of polarization
- Small permanent magnets
- Efficient detection system

Estimated number of shifts: ^{33}Na, ^{33}Mg

β-NMR Spectroscopy End Station

2.2.3 V_{ud} from the β asymmetry parameter of mirror β transitions

N. Severijns, G. Neyens, M. Bissell

combining Ft values of mirror β transitions with Gamow-Teller/Fermi mixing ratio, ρ, from β-asymmetry parameter, *A*, yields V_{ud} qaurk mixing matrix elem.

$$Ft^{mirror}\left(1+\frac{f_A}{f_V}\rho^2\right) = 2Ft^{0^+\to 0^+} = \frac{K}{G_F^2 V_{ud}^2 (1+\Delta_R^V)}$$

from β asymmetry

O. Naviliat, N. Severijns,
PRL 102 (2009) 142302,
Phys. Scr. T152 (2013) 014018

most sensitive case turns out to be the β-asymmetry parameter of ^{35}Ar;

relative precision of 0.5 % on $A(^{35}Ar)$ yields V_{ud} with abs. precision of 0.0004

V_{ud} ($0^+ \rightarrow 0^+$) = 0.97425 ± 0.00022

only factor of 2 difference !!

- polarize ^{35}Ar using collinear optical pumping and implant in host lattice
- measure β asymmetry with two ΔE-E telescopes (0° and 180° w.r.t. polar. dir.)
- avoid need for precise determination of nucl. polar. by relative measurement of β asymmetry for mixed mirror trans. and pure GT trans. to excited state
- ^{21}Na and/or ^{23}Mg to optimize method while developing polarized ^{35}Ar beam

Estimated number of shifts: ^{21}Na, ^{23}Mg, ^{35}Ar

Summary and Outlook

VITO project:

- Dedicated beamline with laser-induced spin-polarization at ISOLDE
- Three end stations: ASPIC, β-NMR and travelling experiments
- Versatile and multidisciplinary experiments (solid state physics, nuclear physics, biophysics)
- Modification of an existing UHV line, polarization assembly from COLLAPS collaboration

Beam time request (2014 – 2016):

- 7 proposals and LoIs (only in the first round)
- Approx. 70 shifts spread over a period of 2-3 years, starting in 2014 (20 different isotopes)

Advantages:

- Upgrade of an existing beamline
- ASPIC chamber maintained, restarted, ready for off-line experiments in 2013
- β-NMR setup from tilted foil assembly
- one open end station for travelling experiments