Recent developments in β-NMR

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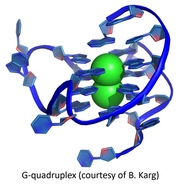
Why β-NMR?

- Very high sensitivity compared to NMR
  a. Hyperpolarization of nuclei
  b. Detection of anisotropy in β-decay
- Study of molecular structure and dynamics
- Real-time observation of chemical reactions

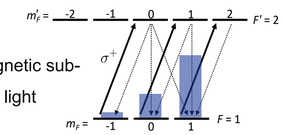


G-quadruplex (courtesy of B. Karg)

Working principle

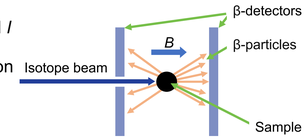
a. Laser-induced optical pumping

- *B*-field causes Zeeman-splitting
- Excitation of selected hyperfine magnetic sub-states with circularly-polarized laser light
- Polarized atomic spin $F = I + J$



b. Asymmetry in β-decay

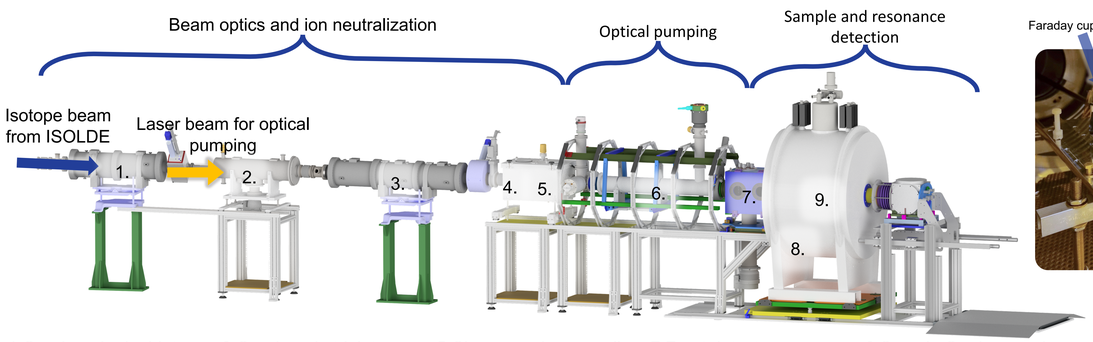
- Strong *B*-field decouples spins *J* and *I*
- Asymmetry in β-decay due to violation of parity of the weak force
- High detection efficiency



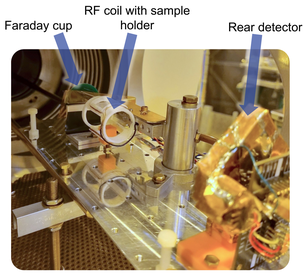
Latest Upgrades

- Superconducting magnet (sub-ppm homogeneity and temporal stability)
- Advanced beam diagnostics and optics
- New detectors
- New data acquisition system

VITO beamline



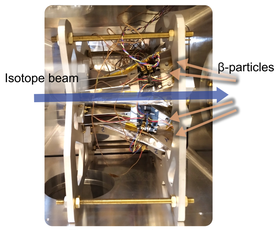
1.Quadrupole doublet
2.Five degree bender
3.Quadrupole triplet
4.Doppler tuning electrode
5.Charge exchange cell
6.Optical pumping section
7.Front detector
8.Superconducting magnet
9.Sample Carriage and rear detector



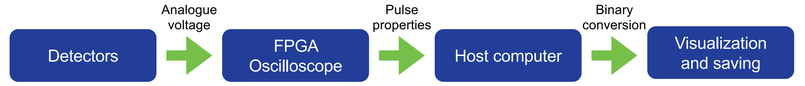
Retractable sample carriage

New data acquisition system

- Combined control system for the setup and data acquisition system
- Robust, automated measurement routines
- NI PXIe crate with 250 MHz, 14-bit oscilloscope at its core
- Option to stream raw data from detectors to the host computer
- FPGA computes pulse properties in real time
- *Time-resolved* information for each β-particle (timestamp, amplitude, time over threshold, integral etc.)

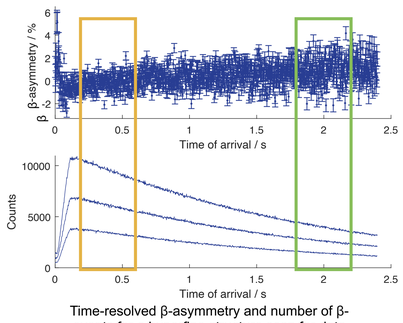


The new front detector



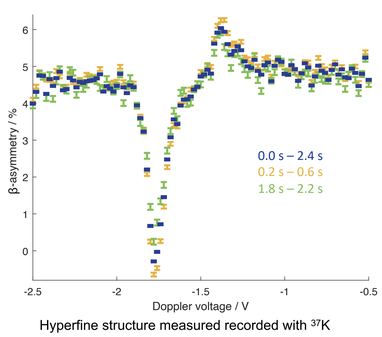
Advantages of the upgraded setup

- Time-resolved data enables to choose observation window for each measurement



Time-resolved β-asymmetry and number of β-events for a hyperfine structure scan for data points in resonance with optical pumping laser

- Allows to select the time window with the highest asymmetry of β-events

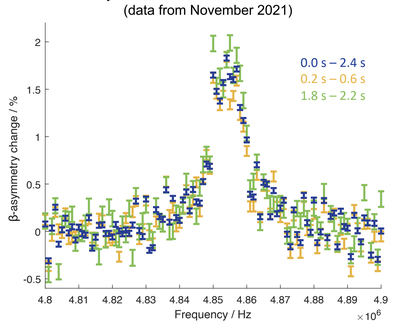


Hyperfine structure measured recorded with ^{37}K

- Adaptable to relaxation times for hyperfine structure scans and NMR even after the experiment
- Trade-off between degree of β-asymmetry change and number of beta events
- Find best ranges of signal amplitude and time of arrival for different samples

→ More adaptable and sophisticated data analysis possible

Example for an NMR resonance of ^{37}K in a KBr crystal with different observation windows (data from November 2021)



Conclusions

- Highly improved sensitivity, resolution, and functionality compared to previous setup
- Time-resolved data with properties recorded for each β-event
- Enhanced data analysis possible, allows to adapt for each measurement
- Opens path for new biological and chemical studies and more isotopes
- Successful polarization and NMR studies with sodium and potassium in September and November 2021

References

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