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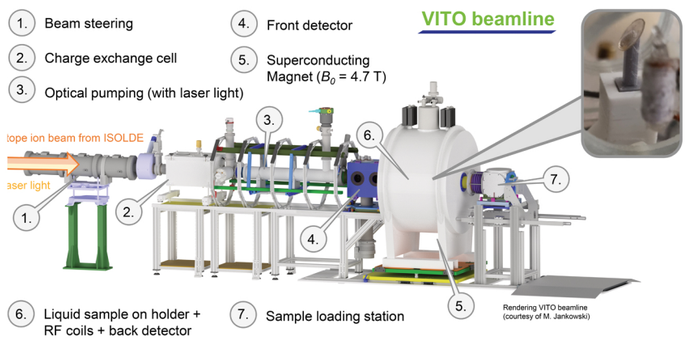
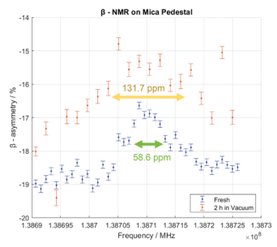
Development of a Liquid Sample Dispensing System Facilitating Novel Applications of β-NMR at VITO



VITO beamline

Sample holder

- **Old system:** Liquid droplet on pedestal with mica
- **Disadvantages:**
  - → Increasing **background** activity in sample with time due to daughters ⇒ SNR gets bad
  - → **Broadening** of **Glycholine** resonance **peaks** the longer sample in vacuum
    - ↪ Reason: **less molecular tumbling** as water components evaporate in vacuum over time
    - ↪ **Sample change** required after ~ 2 hours which costs **time**

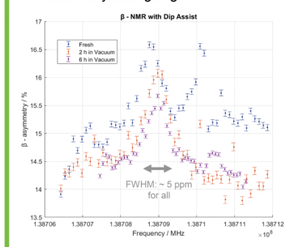


New system – "Dip Assist"

- Aim: Constantly **fresh sample** droplets without venting
- Improved sample holding system → **"The Spoon"**
- Circular opening 5 mm filled with sample liquid
  - ↪ plane-parallel to incoming beam
  - ↪ **constant flow** of fresh liquid through 0.8 mm capillary
  - ↪ old sample droplet falls down after some time
- Lockable 2.2 mL sample liquid reservoir → **"The Dispenser"**
  - ↪ **held close** by non-magnetic spring
  - ↪ openable to let new sample liquid flow into the spoon

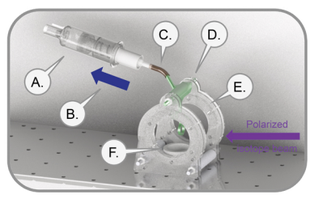
Results & Outlook

- Sharp peaks even after **hours**
  - → **No** more peak **broadening**
  - → FWHM: few ppm
- Data analysis ongoing

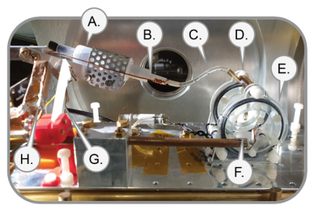


→ System **ready to use** for further studies providing narrow resonances

Implementation in beamline



- Mounting **adapted spoon** in between RF-coils
- **Pulling mechanism** to open liquid reservoir of dispenser
  - ↪ copper wire + brass stick connected to mechanical feedthrough
- Funnel and container (below carriage) form **liquid collection system** picking up droplets
- Several tests ran prior to beamtime prove functionality
- Designing online **observation system**
  - ↪ rotatable LED behind sample → used between measurements
  - ↪ observation + recording via optics on laser table
  - ↪ facilitates adjustment of laser position



(A.) Dispenser (B.) Pull feedthrough to open dispenser
(C.) Tube dispenser ↔ spoon (D.) Adapted spoon
(E.) RF-coils (F.) Funnel to liquid collector (below carriage)
(G.) Moveable LED (observation system) (H.) Back detector

References & Acknowledgments:
[1] B. Karg: Liquid β-NMR studies of the interaction of Na and K cations with DNA G-quadruplex structures. CERN INTC-P-560, 2020.
[2] R. D. Harding, M. Kowalska: Magnetic Moments of Short-Lived Nuclei with Part-per-Million Accuracy: Toward Novel Applications of β-Detected NMR in Physics, Chemistry, and Biology. Physical Review X, 10(4), 2020.
Data analysis scripts by M. Jankowski. Funding provided by the ERC.

β-NMR has proven its capabilities and advantages in the world of nuclear spectroscopy: Not only does it open the door to high precision measurements of nuclear properties, but it also facilitates investigations of unstable, short-lived isotopes, otherwise inaccessible to conventional NMR. Additionally, β-NMR allows for real-time observations of chemical processes, such as biomolecular folding mechanisms.

Recently, the VITO collaboration has been striving towards novel applications of this technique in interdisciplinary fields. One of the ongoing projects aims at investigating the dynamics of selected DNA structures and their interaction with different alkali metals. Deep eutectic solvents, such as Glycholine, are used as hosts for these biological samples.

Performing experiments with liquid samples in a high vacuum setup poses technical challenges, not faced in typical nuclear spectroscopy. So far, a simple support with a plate on top is used to position the liquid sample for beam implantation. Exchanging the droplet, however, is time consuming, as it requires venting and opening the beamline. At the same time, prolonging the measurement duration without changing the sample would increase background activity from daughter nuclides, thus introducing additional noise.

Addressing this issue, a new project has been launched at the VITO beamline, aiming to develop, test and implement a new sample holding and dispensing system. Not only does the design presented with this poster contribution reduce the need of opening the beamline, but it continuously provides fresh samples for implantation. Thereby, it contributes to a more efficient measurement process and an enhanced signal to noise ratio.

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