

21.03.2023

Praktische Probleme der Kernresonanzspektroskopie 2023
Berlin

BENCHTOP-NMR-SPEKTROSKOPIE

Praktische Probleme in Labor- und Prozessanwendungen

Klas Meyer, Martin Bornemann-Pfeiffer, Isabel Thiele, Björn
Gutschmann, Sebastian L. Riedel, Stefan Falkenstein, Tino Döring,
Matthias Abele, Peter Neubauer, Michael Maiwald

Benchtop-NMR-Spektroskopie

“Easy-to-use”

The flag ship Nanalysis benchtop NMR spectrometer! The only all-in-one, **easy-to-use** compact NMR spectrometer

- High-performance, multinuclear NMR spectra
- Advanced features and experiments
- Market-leading compact size and shape



Available in two models:

- 60PRO – multinuclear
- 60e – single nuclei

Quelle: <http://www.nanalysis.com>

The world's only broadband benchtop NMR system, X-Pulse allows you to freely tune between a wide range of X-Nuclei in a single benchtop NMR instrument.

Resolution <math><0.35\text{ Hz (50\%)} / <10\text{ Hz (0.55\%)}</math>

Sensitivity: 130:1 for 1% Ethyl Benzene

X-Channel: fully tuneable ^{29}Si – ^{31}P

Pulsed field gradients as standard ($>0.5\text{ T/m}$)

Variable temperature option (0°C – 65°C)

Flow NMR option

No cryogenes

Easy to use

Standard 5mm OD NMR tubes



Quelle: <http://nmr.oxinst.com>

NMR INSTRUMENTS

Fourier 80

Advance your analytical capabilities and strengthen your curriculum with high-performance NMR in an **easy-to-use** compact benchtop system. Tackle the challenges. Remove the barriers. Advance discovery.



Quelle: www.bruker.com

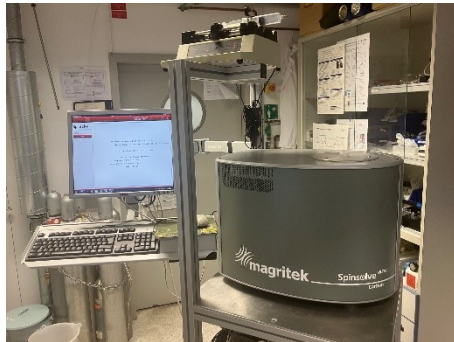
Features of Spinsolve 60 MHz

- ^1H frequency: 60 MHz
- ^1H and ^{19}F on all systems + X nuclei for dual channel systems
- Resolution:
 - Spinsolve 60 : $<0.5\text{ Hz (50\%)} / <20\text{ Hz (0.55\%)}</math>$
 - Spinsolve 60 Plus: $<0.35\text{ Hz (50\%)} / <10\text{ Hz (0.55\%)}</math>$
 - Spinsolve 60 Ultra: $<0.2\text{ Hz (50\%)} / <7\text{ Hz (0.55\%)} / <14\text{ Hz (0.11\%)}</math>$
- Exceptional Sensitivity: 200:1 (Single channel) / 130:1 (Double channel) for 1% Ethyl Benzene
- 3D PFG gradients optimized for gradient-enhanced methods
- Optional PFG gradients for diffusion spectroscopy ($>0.5\text{ T/m}$)
- No cryogenes
- Unparalleled stability
- External Hardware Lock with no need for deuterated solvents
- Suitable for on-line reaction monitoring
- **Easy to operate**
- Compatible with automatic sample changer

Quelle: www.magritek.com



Benchtop-NMR-Spektroskopie @ BAM



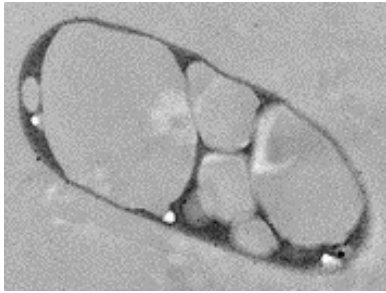
Beispiel 1: Extraktion von PHB(Co-HHx)

Aufarbeitungsschritt eines Bioprozess

www.bam.de

Einführung PHB(Co-HHx)

Poly(hydroxybutyrate-co-hydroxyhexanoate)

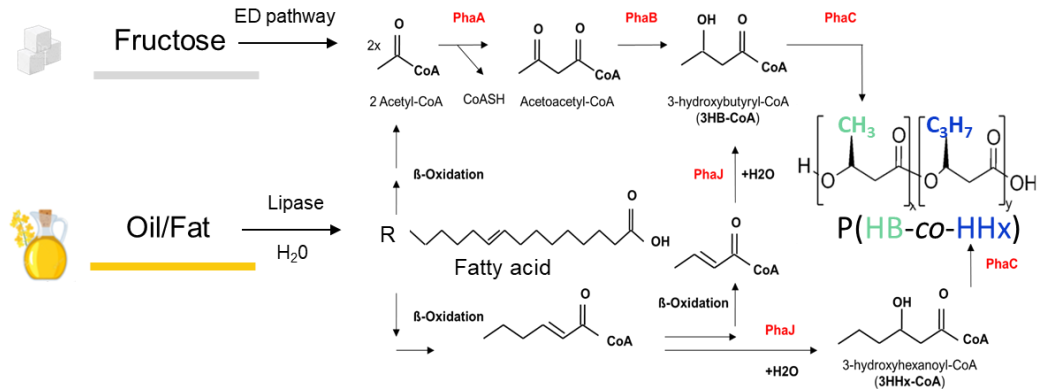


TEM of *R. eutropha* Re2058/pCB113 cells containing PHA (provided by Sudesh Kumar and Manoj Lakshmanan, USM)

- Linearer Polyester aus Bioprozess (z.B. mit *Ralstonia eutropha*)
- Nahezu vollständig bioabbaubar zu CO₂ und H₂O
- HHx-Gehalt abhängig von Substrat - Materialeigenschaften
- Polymer ist auf klassischen Anlagen verarbeitbar

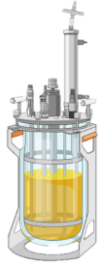


renewablecarbon.eu



Adapted from Budde et al. 2011

Herstellung und Extraktion



5 L Batch Kultivierung
(recombinant *R. eutropha*)



Gefriertrocknung/Mahlung

- 67.8 ± 2.0 wt-% P(HB-co-HHx)
- ~ 13.5 mol-% HHx

On-line monitoring



Benctop NMR




Extraktion



**Proben-
vorbereitung**

Off-line

- PHA Gehalt
- Reinheit
- Zusammensetzung

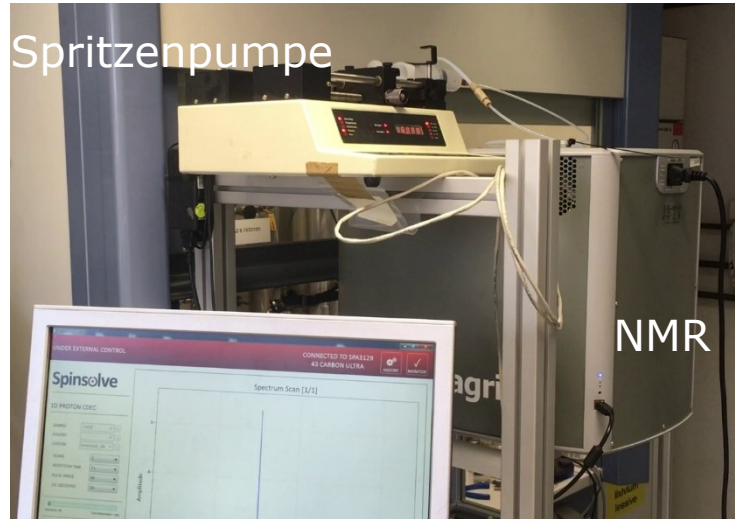


GC

HF-NMR

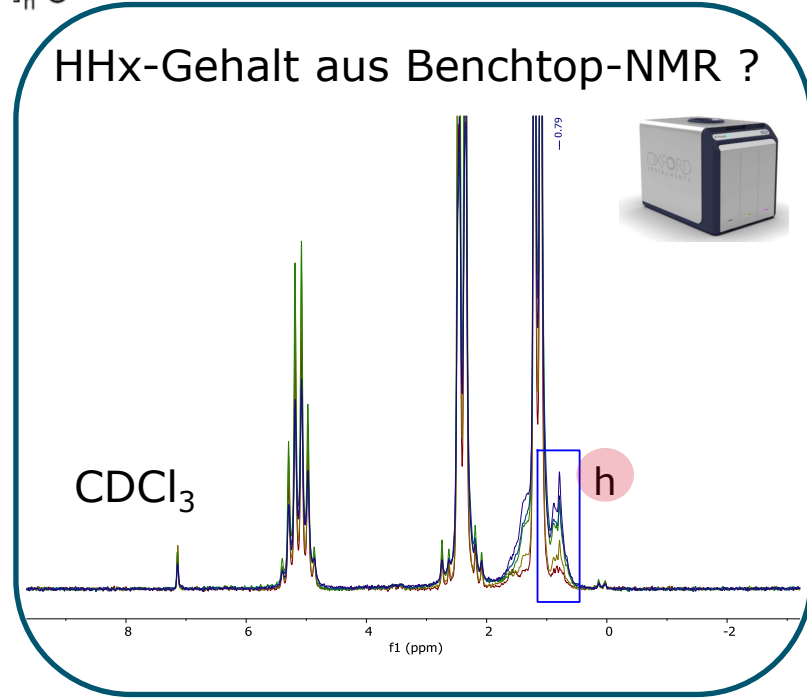
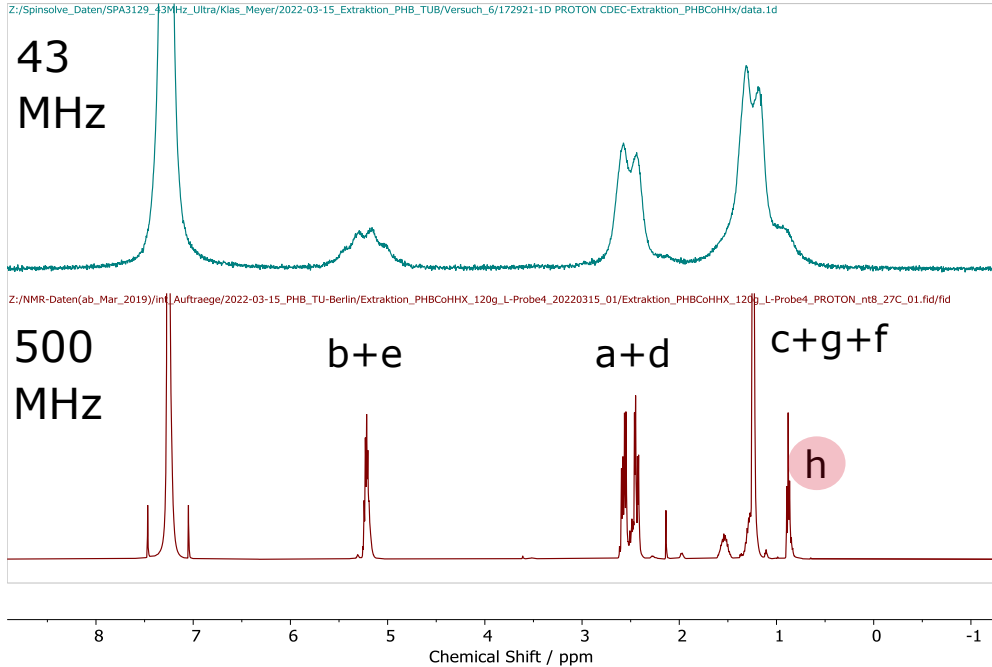
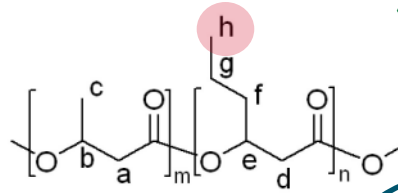
Versuchaufbau BAM

- Extraktion in einem 150 mL Glasreaktor
- Messung im 5x4 mm PTFE-Schlauch
- Vollautomatische Sequenz mit Spritzenpumpe (1:20 min / Messpunkt)



NMR-Spektren

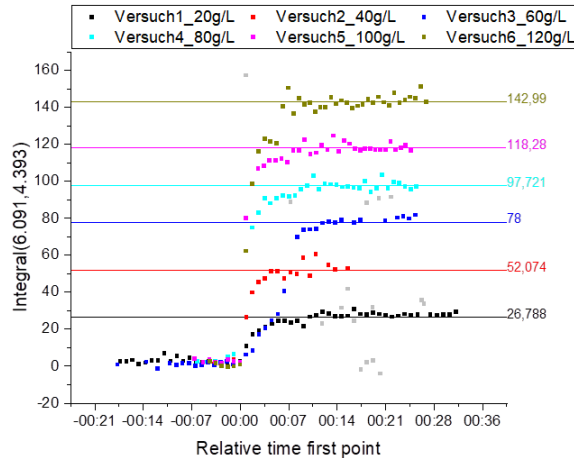
PHB(Co-HHx) – 120 g/L in CHCl₃



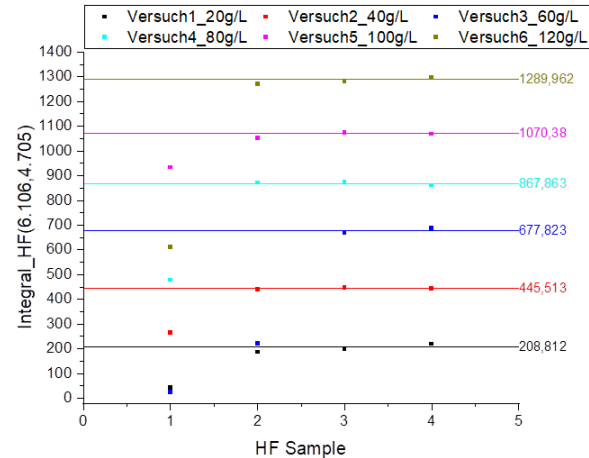
Ergebnisse

Extraktion in CHCl_3 unter Variation Zelldichte

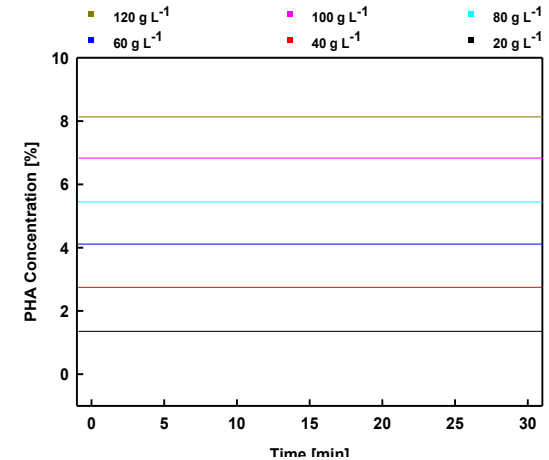
Online-NMR



Offline HF-NMR



Offline GC

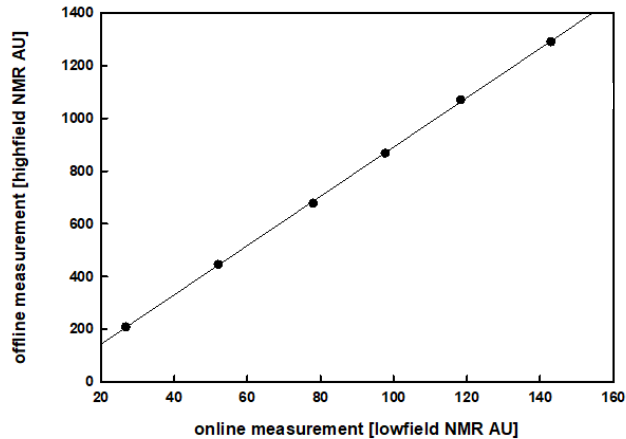


- Extraktion verläuft sehr schnell (aktuelle Verfahren 3 h deutlich kürzbar)
- Prozessabweichungen detektierbar (**Versuch 3**, Zellmaterial auf Oberfläche)

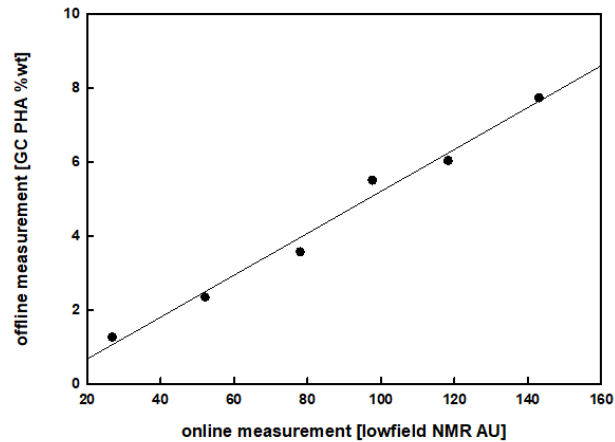
Ergebnisse Methodenvergleich

Paritätsplots zwischen NMR und GC

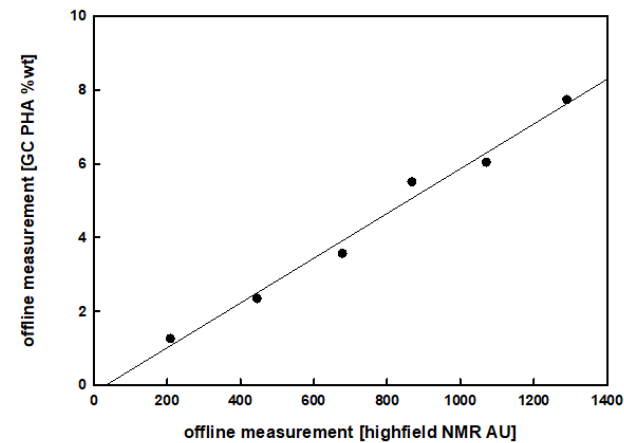
Benchtop- vs. HF-NMR



Benchtop-NMR vs. GC



HF-NMR vs. GC



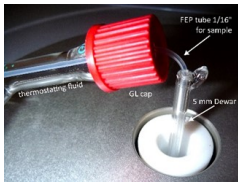
- Gute Übereinstimmung zwischen NMR- und GC-Methode
- Weitere Online-Versuche unter Variation von Lösungsmitteln und Temperatur

Beispiel 2: Aktive Temperaturisolierung

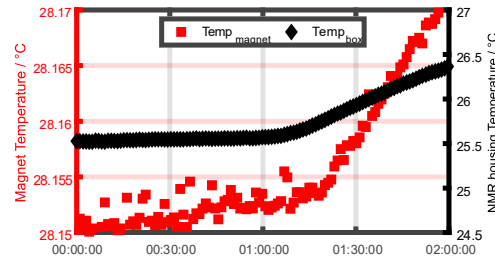
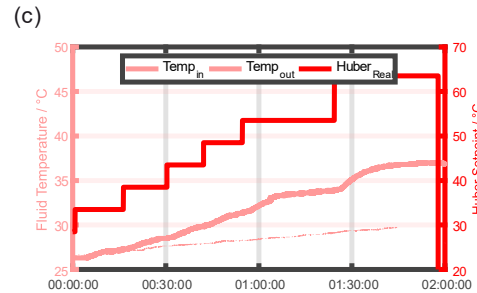
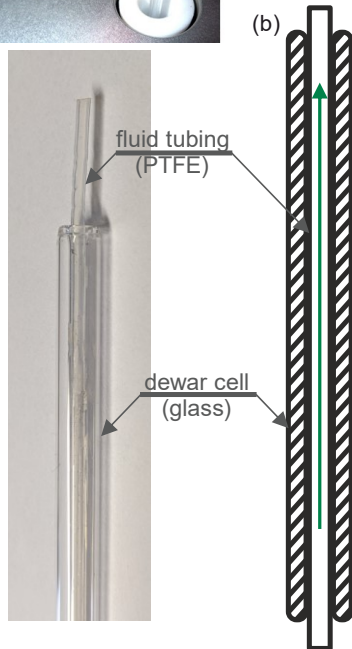
www.bam.de

Einführung/Motivation

Temperatur derzeit DIE Limitierung im Prozesseinsatz



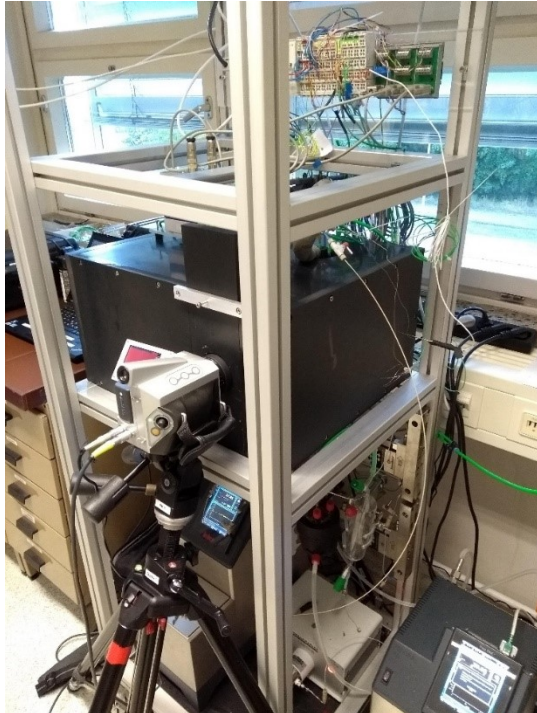
Passive Isolation mit Dewar



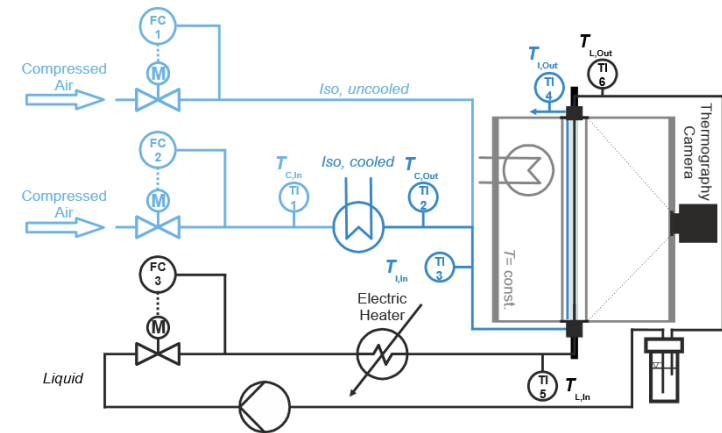
- Wärmeeintrag trotz passiver Isolation zu hoch
- Aktive Regelung speziell für dynamische Systeme notwendig
- Limitierung derzeit Platz im Magneten (5 mm Bohrung)
- Entwicklungen mittels Prototyp-System (Nanalysis PAT-Pilot, 12 mm)

Aktive Isolation mit Luftströmen

Thermographie-Untersuchungen an "Blackbox"

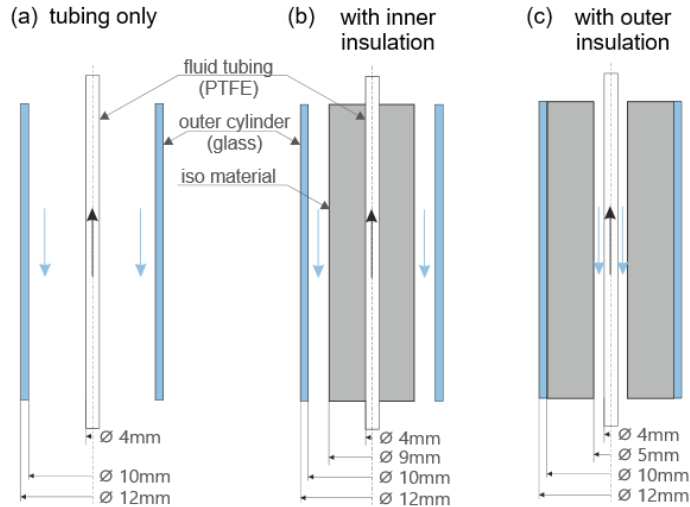


- Nachbildung Einbaumgebung NMR
- Oberflächentemperatur mittels Thermographiekamera



Aktive Temperaturisolation

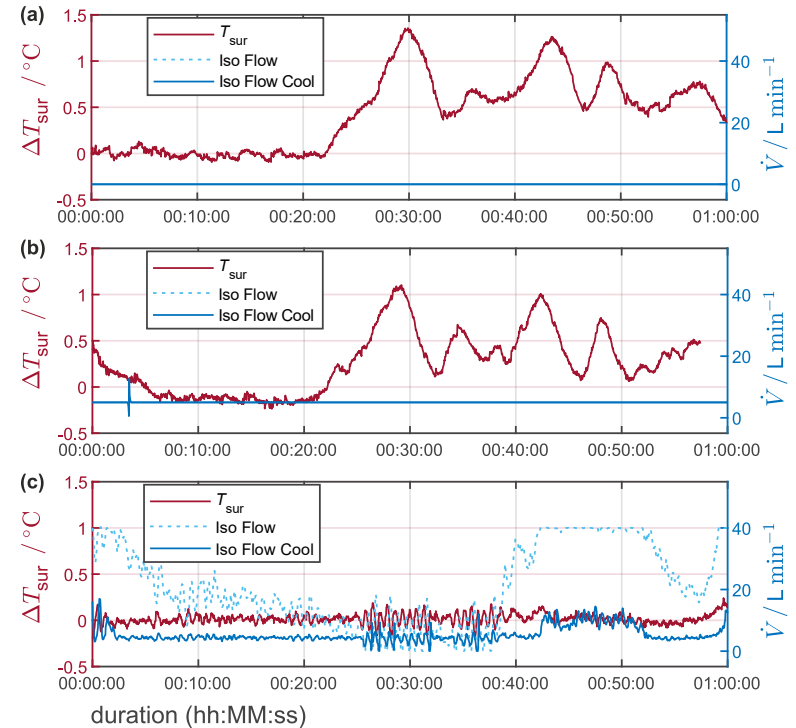
Unterschiedliche Isolationskonzepte



Off

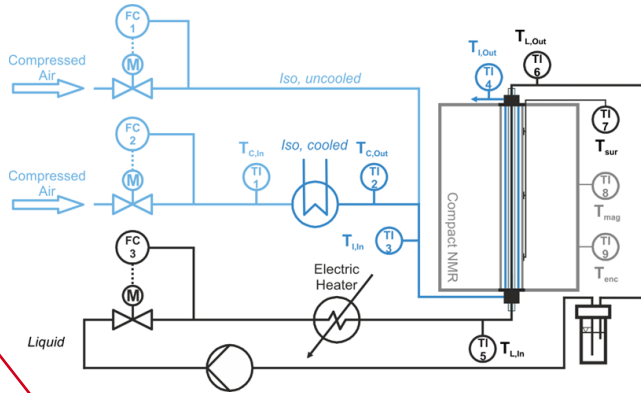
Steady
5 L/min

Control



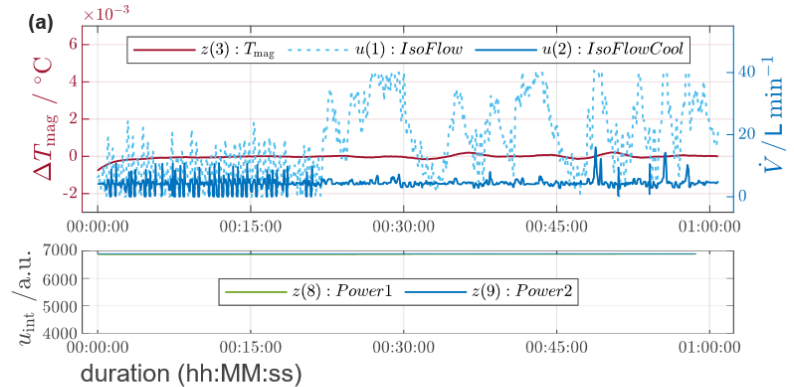
Kombination mit passiven
Isolationen bei verfügbaren
Abmessungen ineffektiv

Transfer ins NMR-System

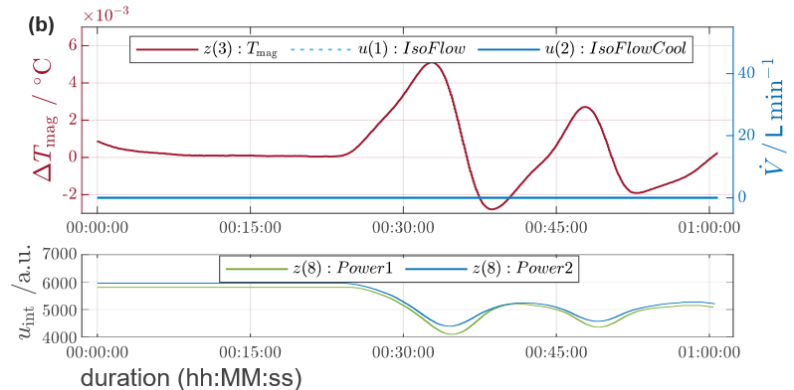


Thermoelemente für Eingangsgroßen direkt im Glas-Aufbau

geregelt



ungeregelt



Ausblick: Benchtop NMR in ATEX-Zonen

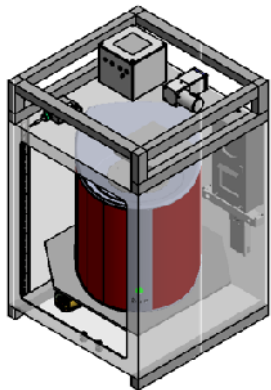
www.bam.de

Einhausung für ATEX-Anwendungen



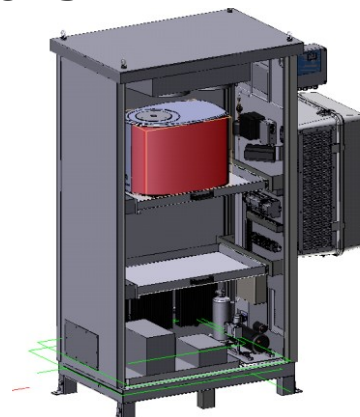
Aktueller Stand

1st Generation 2017



- Modulmaße
- Wärmetauscher

2nd Generation 2023



- Flexibilität
- Klimatisierung
- Sekundärmethode (opt. Spektroskopie)



Danke für die Aufmerksamkeit !

www.bam.de