



# Non-destructive, in-situ, in-operando Material Testing

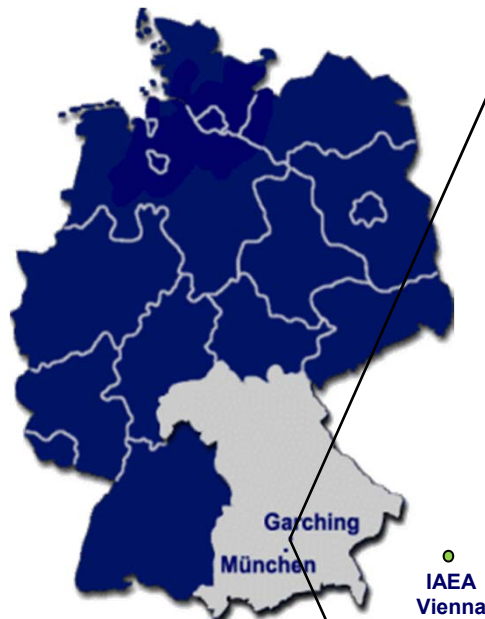
**Winfried Petry**

Scientific Director FRM II





# Neutron Source FRM II on TUM Campus in Garching

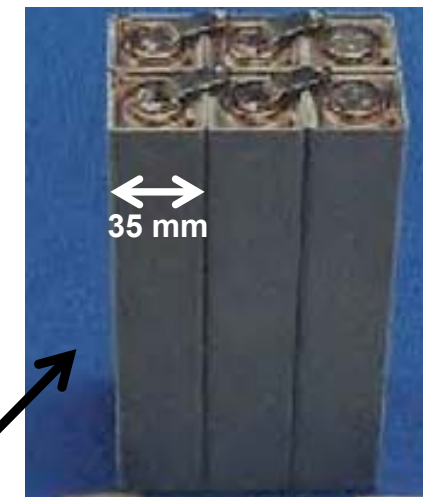




# ZEBRA Battery – (Zeolithe Battery Research Africa) Na/(Ni/FeCl) Battery

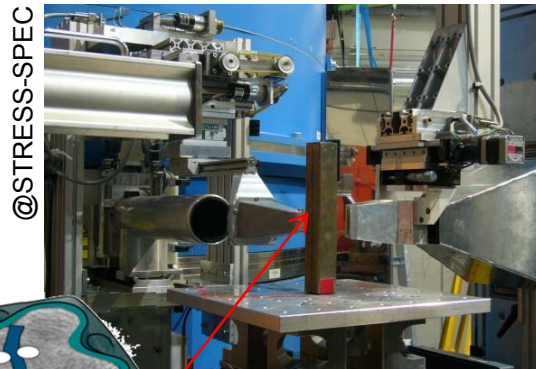
## Properties:

- high energy density
- high reliability > 1000 cycles
- low cost of material (Ni, Fe)
- operating temperature: 270 °C – 350 °C

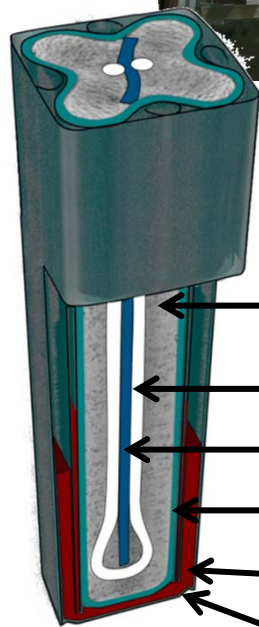


*hybrid railway locomotives*

# In-operando: Time resolved Phase Analysis of a Sodium Metalchlorid Battery (Na-FeCl<sub>2</sub>)

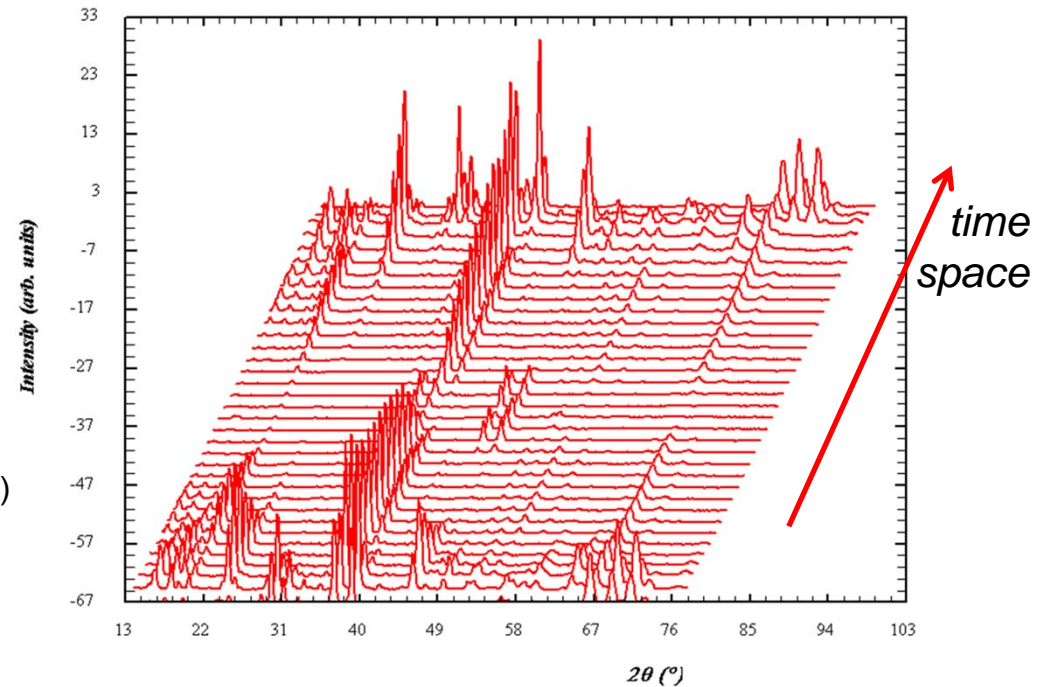
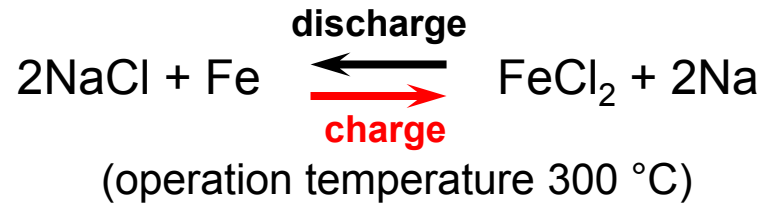


@STRESS-SPEC

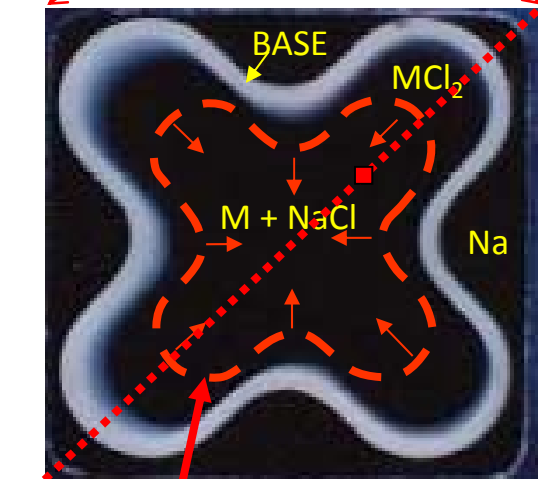
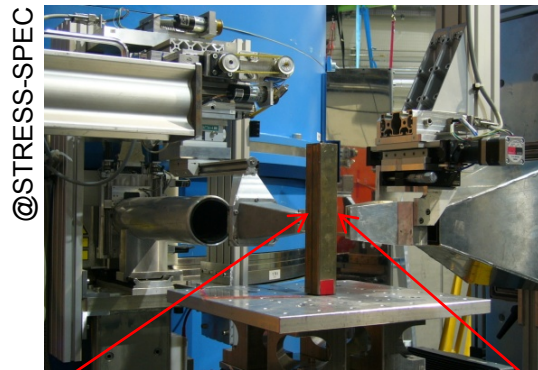


## Cell setup:

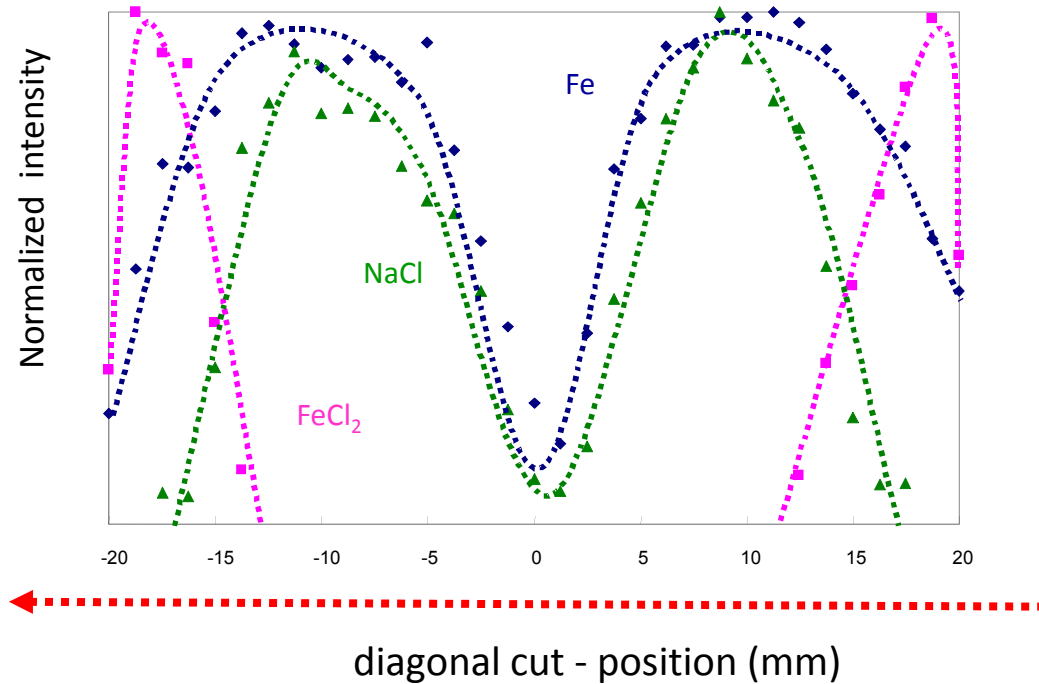
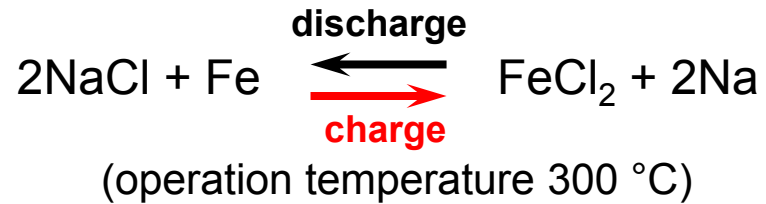
- Cathode: Fe,Ni/ Ni<sub>1-x</sub>Fe<sub>x</sub>Cl<sub>2</sub>/ NaCl
- NaAlCl<sub>4</sub> (liquid electrolyte)
- Cathode current collector
- Electrolyte reservoir (porous graphite)
- β"-alumina (separator, conducts Na<sup>+</sup>)
- Anode: liquid sodium
- Steel case (anode current collector)



# In-operando: Space resolved Phase Analysis of a Sodium Metalchlorid Battery (Na-FeCl<sub>2</sub>)



“Reaction front” moves during charging / discharging

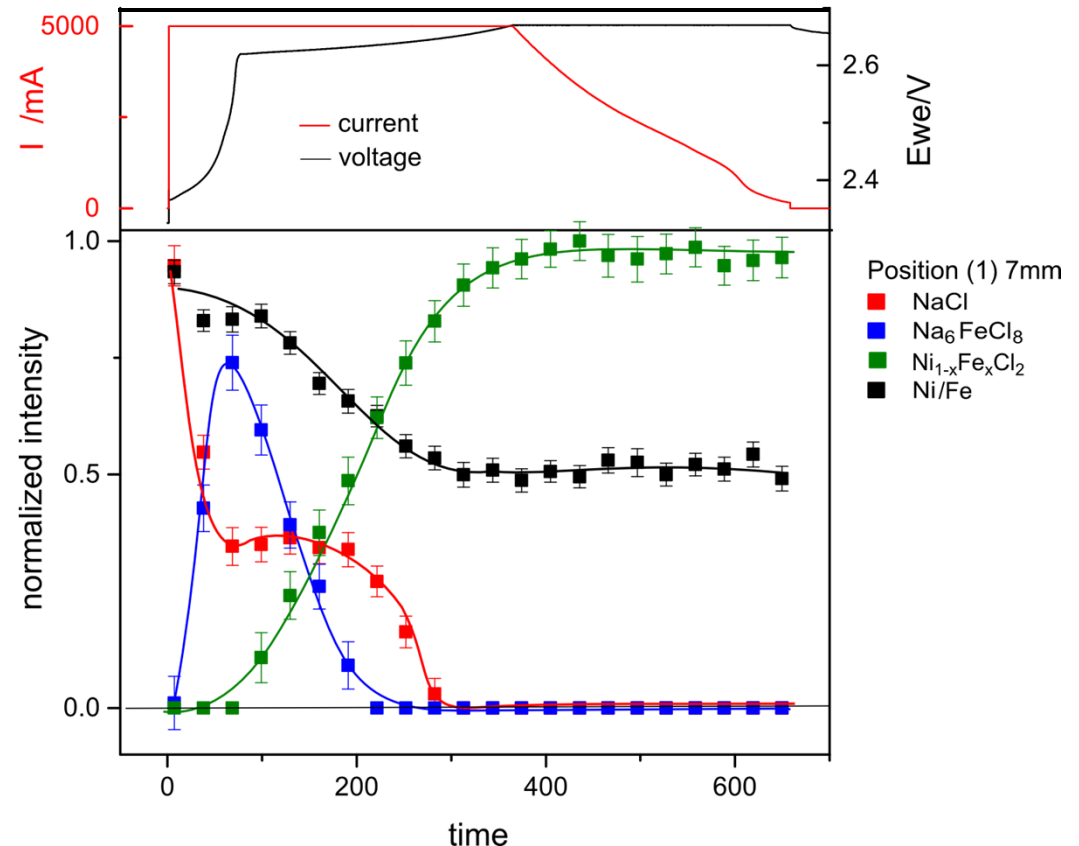


# In-operando: Chemical processes during charging

1. Oxidation of Fe via  $\text{Na}_6\text{FeCl}_8$ :  
Voltage increases quickly to 2.62 V
2. Oxidation of Ni  
Voltage increases slowly to 2.67 V

$\text{Na}_6\text{FeCl}_8$  and NaCl are consumed.

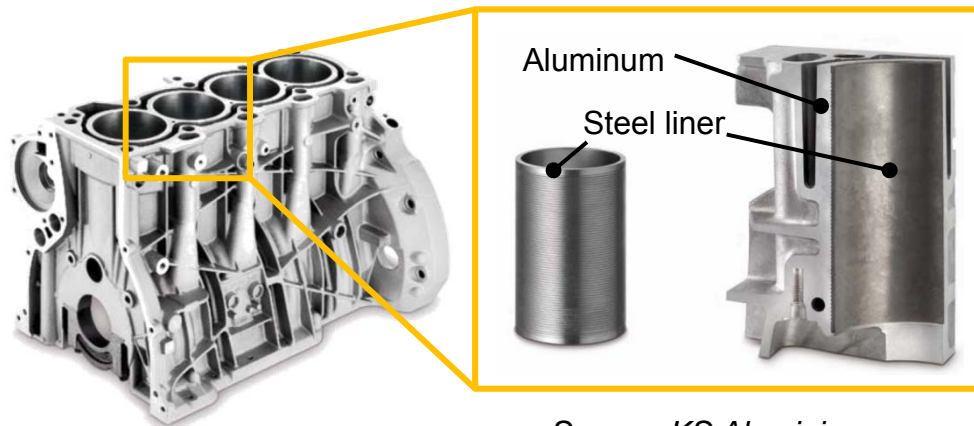
$\text{Ni}_{1-x}\text{Fe}_x\text{Cl}_2$  is formed.



- non-destructive, in-operando knowledge of the molecular processes
- basis for optimization of components to increase the energy density of batteries

## Residual Stresses in a Cylinder Block during the Casting Process

- Measurement of residual stresses in cast part up to now only in the finite state without knowledge how they develop
- Knowledge on residual stresses important for design of cast parts (e.g. engine blocks)
- Behaviour during casting needed as input for FEM simulations



Source: KS Aluminium-Technologie AG

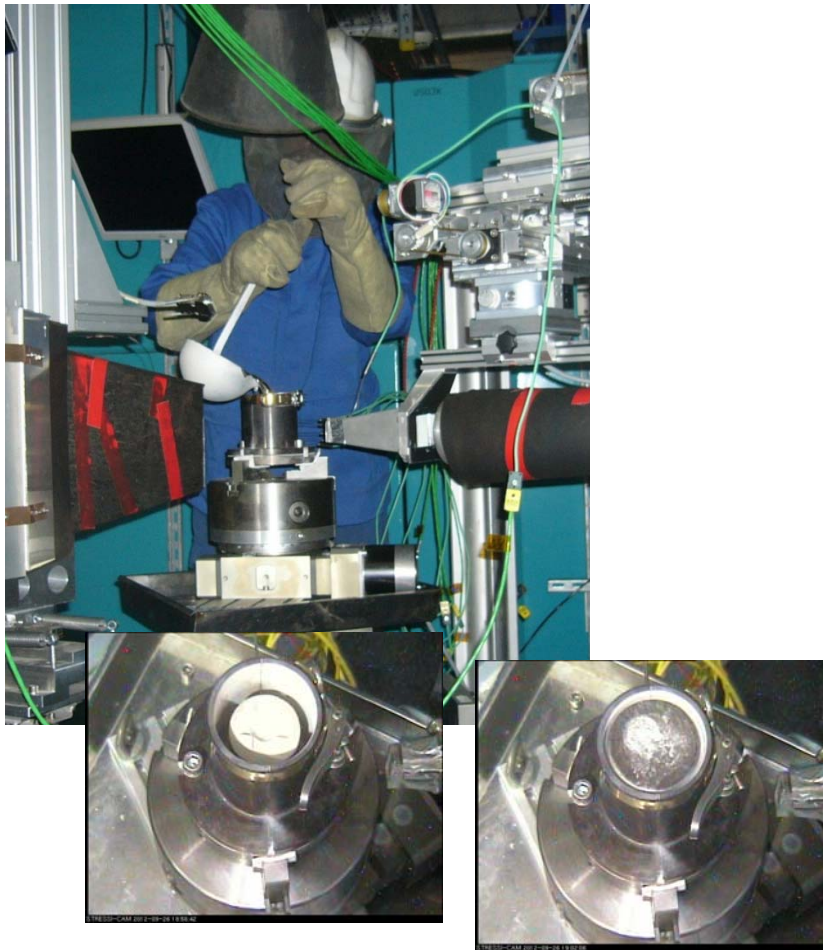


Mock-up sample for neutron diffraction experiment at STRESS-SPEC

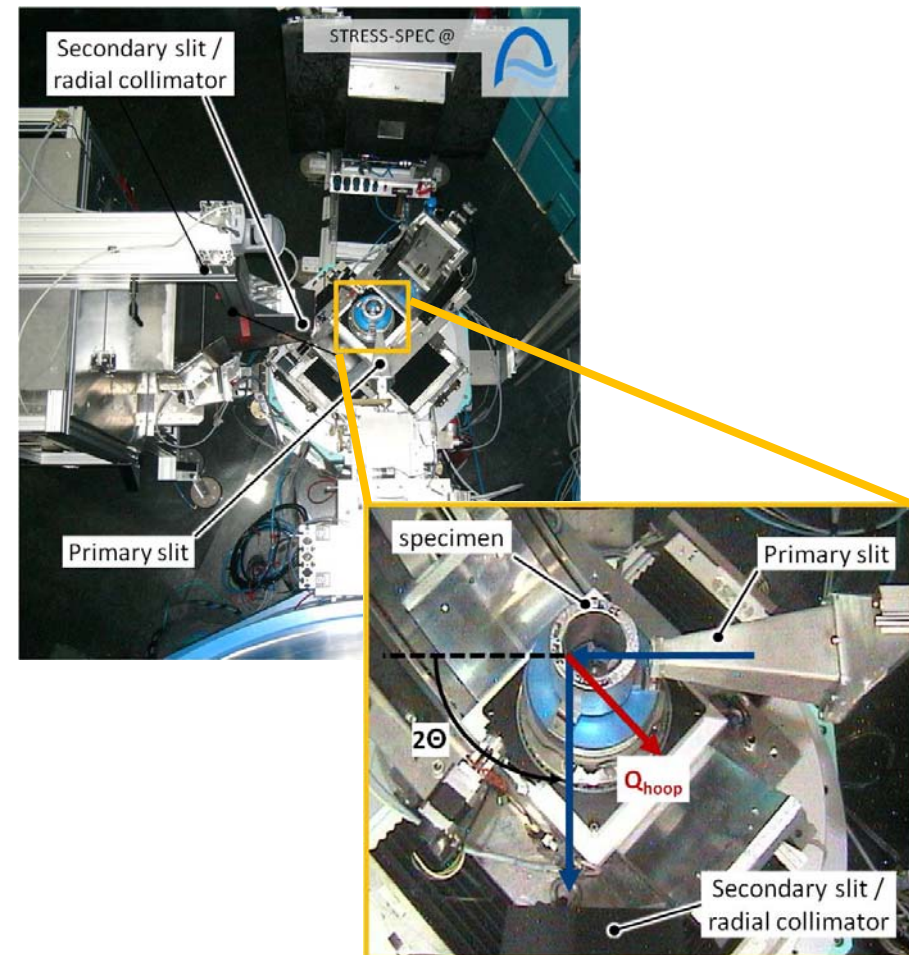


# Residual Stresses during and after the Casting Process

- In-situ measurement

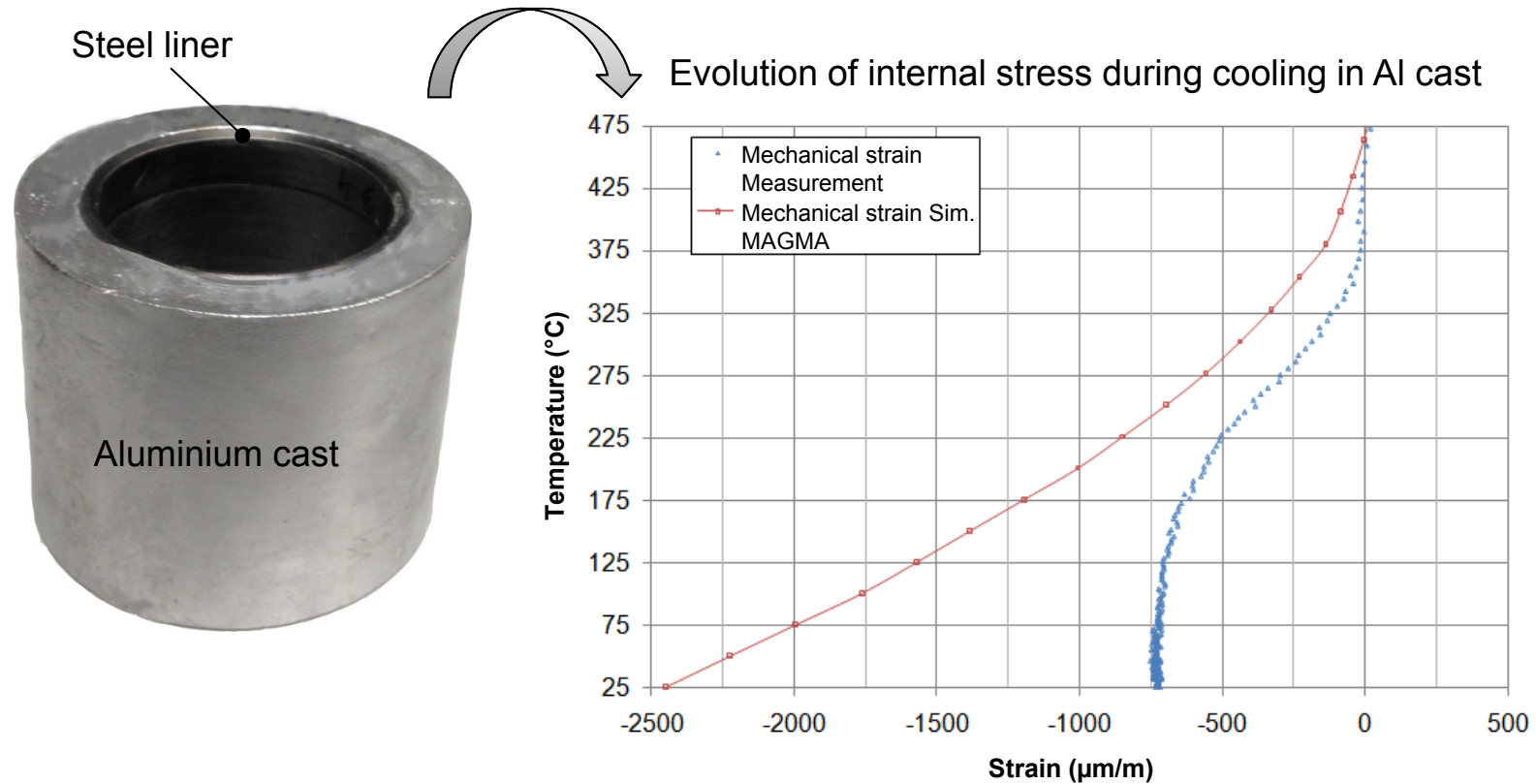


- Ex-situ measurement





# Residual Stresses during the Casting Process



→ Drastically improved numerical simulation of the casting process

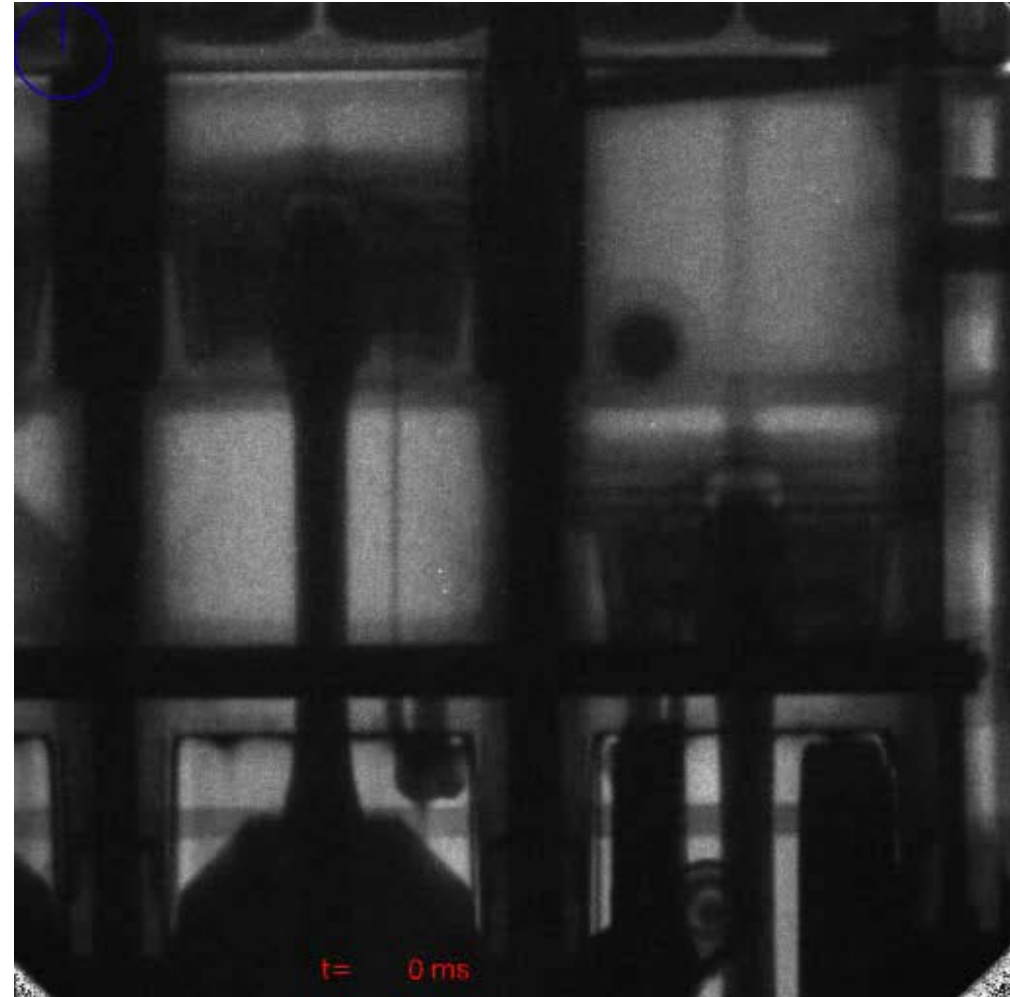
## Make the invisible visible

- High resolution radiography of an engine



- High spatial resolution
- Complex bulky work piece decomposed in its components

## In-operando: Operating Engine in ms time frame



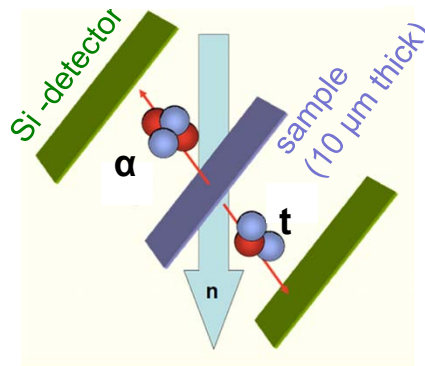
BMW engine – electrically driven



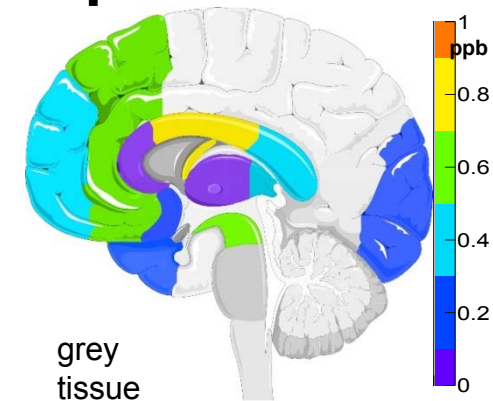
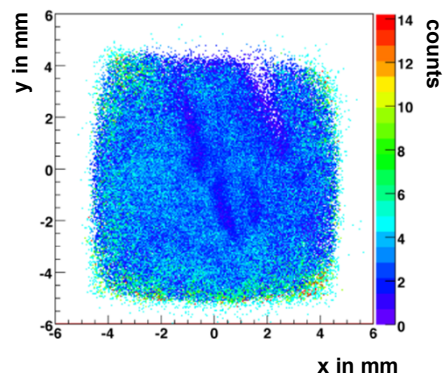
# Material Testing from an alternative point of view: Lithium Traces in Human Brain samples

- Bipolar disorder (manic depression) is a relatively common disease with an overall lifetime incidence of **1%**
- Lithium is an effective antimanic agent.
- Still it is not clear how Lithium works in the brain.
- Generate a Lithium map of the human brain!

Special detector setup:  
sensitivity 0.2 ppb

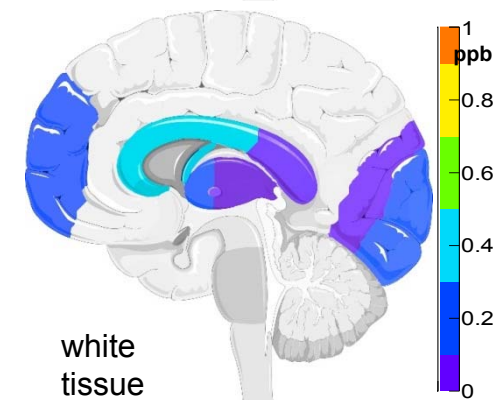


2D Lithium sample



grey  
tissue

*victim of  
suicide  
has less  
lithium in  
white  
tissue ?*

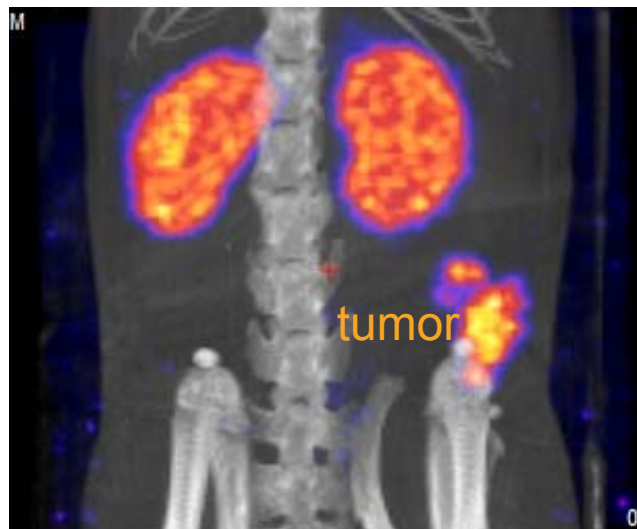


white  
tissue

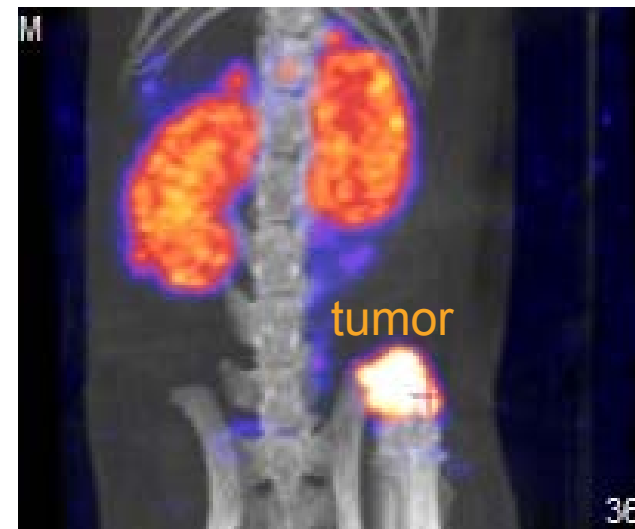
→ Lithium accumulation in white matter observed in a number of depressive patients treated with Li. Li does work in contrast to other psychotropic drugs, within the nerve tracts themselves.

# In-situ imaging & therapy: High specific activity enables reduction of treatments with Lu-177 (n.c.a.)

Scintigraphy of a rat



~300 MBq Lu-177 c.a.  
Dose to tumor: 35 Gy



~300 MBq **Lu-177 n.c.a.**  
Dose to tumor: **70 Gy**

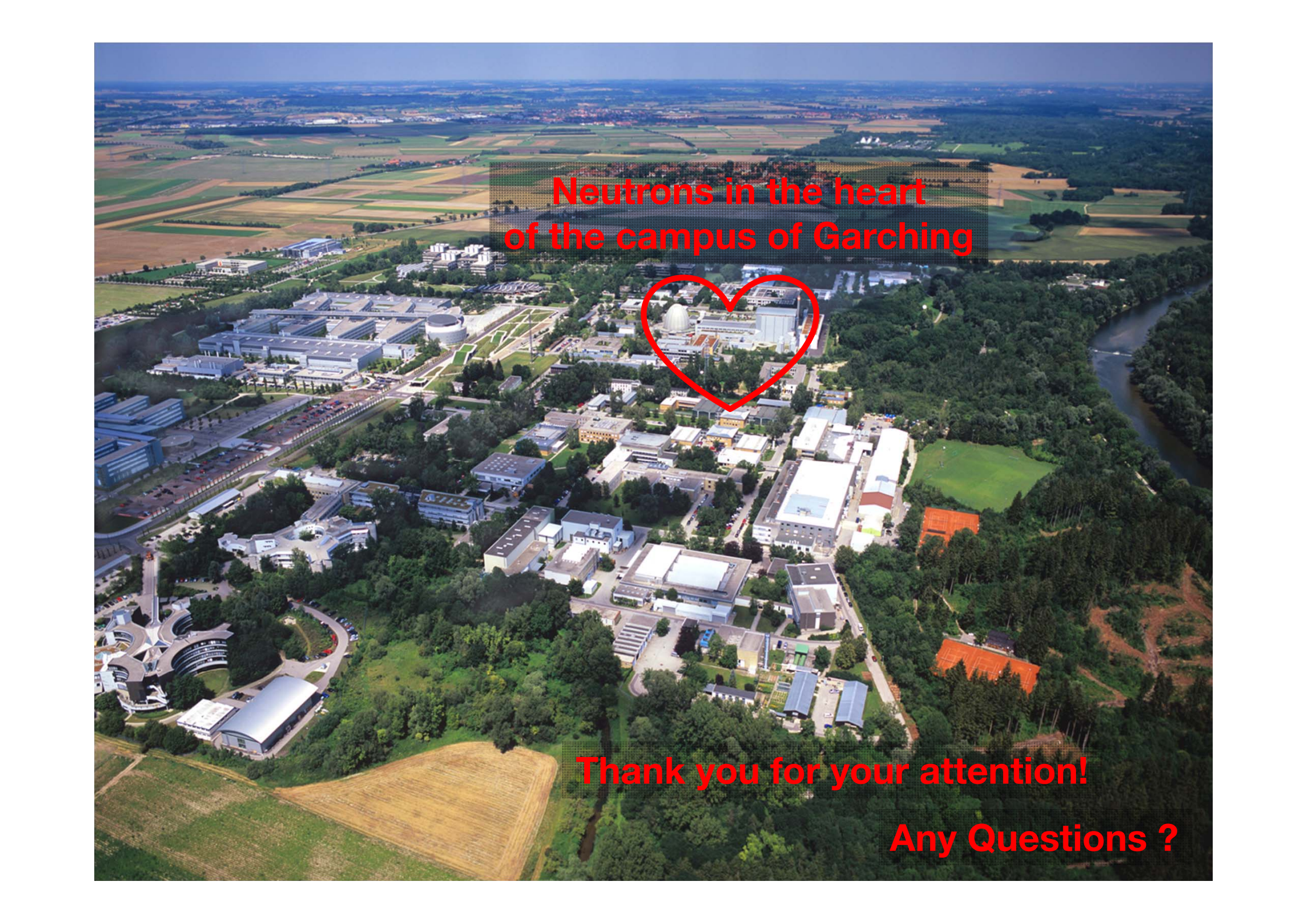
- factor of 2 less irradiation of healthy tissue
- locally a higher dose applied to the tumor



## Radiopharmaceutical industry located on the premises of FRM II





An aerial photograph of the Garching campus, showing a dense cluster of modern buildings and green spaces. A red heart is drawn around the central part of the campus, highlighting the location of the neutron source. The surrounding area includes fields, forests, and a river.

**Neutrons in the heart  
of the campus of Garching**

**Thank you for your attention!**

**Any Questions ?**