The Materials Engineering Diffractometer at ESS: Proposal for an in-kind contribution to the ESS

Andreas Schreyer

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GEMS
German Engineering Materials Science Centre

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Materials Research Agenda

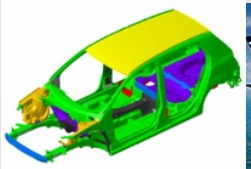
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Mobility and Energy

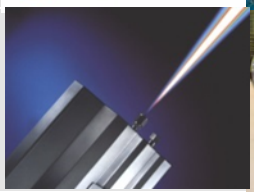
Development of Allyos:
Magnesium | Titanium aluminide

Processing Technologies:
Twin Roll Casting | Welding

Design of Components:
Automobile | Aeroplane



Metal Hydrides and Technologies
for Hydrogen Storage



GEMS processing – in-situ environments

German Engineering Materials Science Centre

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

From raw metal

…to finished part

Casting melting

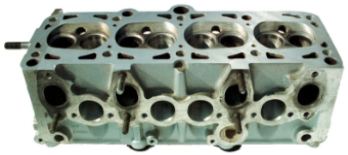
Forging Rolling

Powder atomization

Powder consolidation:
Hot isostatic pressing
Layered Manufacturing
Metal injection moulding

Heat treatment

Cutting
Joining
Welding



GEMS processing – in-situ environments

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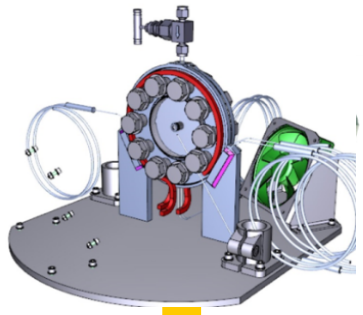
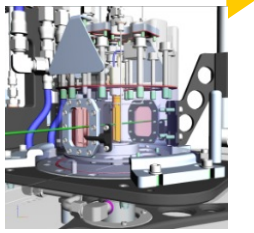
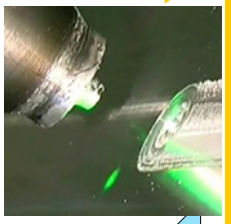


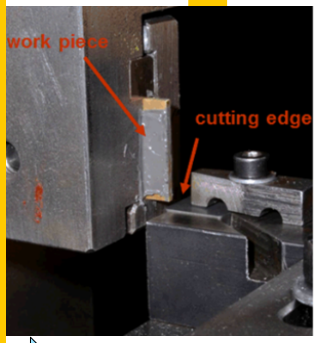
Powder atomization



Powder consolidation:
Hot isostatic pressing
Layered Manufacturing
Metal injection moulding

Cutting
Joining
Welding

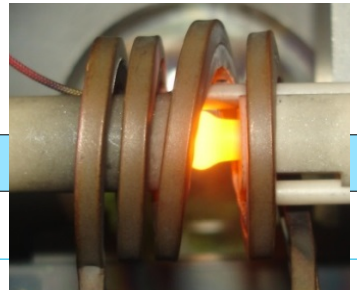




FlexiRoll

FlexiStir

FlexiLas



FlexiTherm

Institute of Materials Research → German Engineering Materials Science Centre (GEMS)

MLZ
Heinz Maier-Leibnitz Zentrum

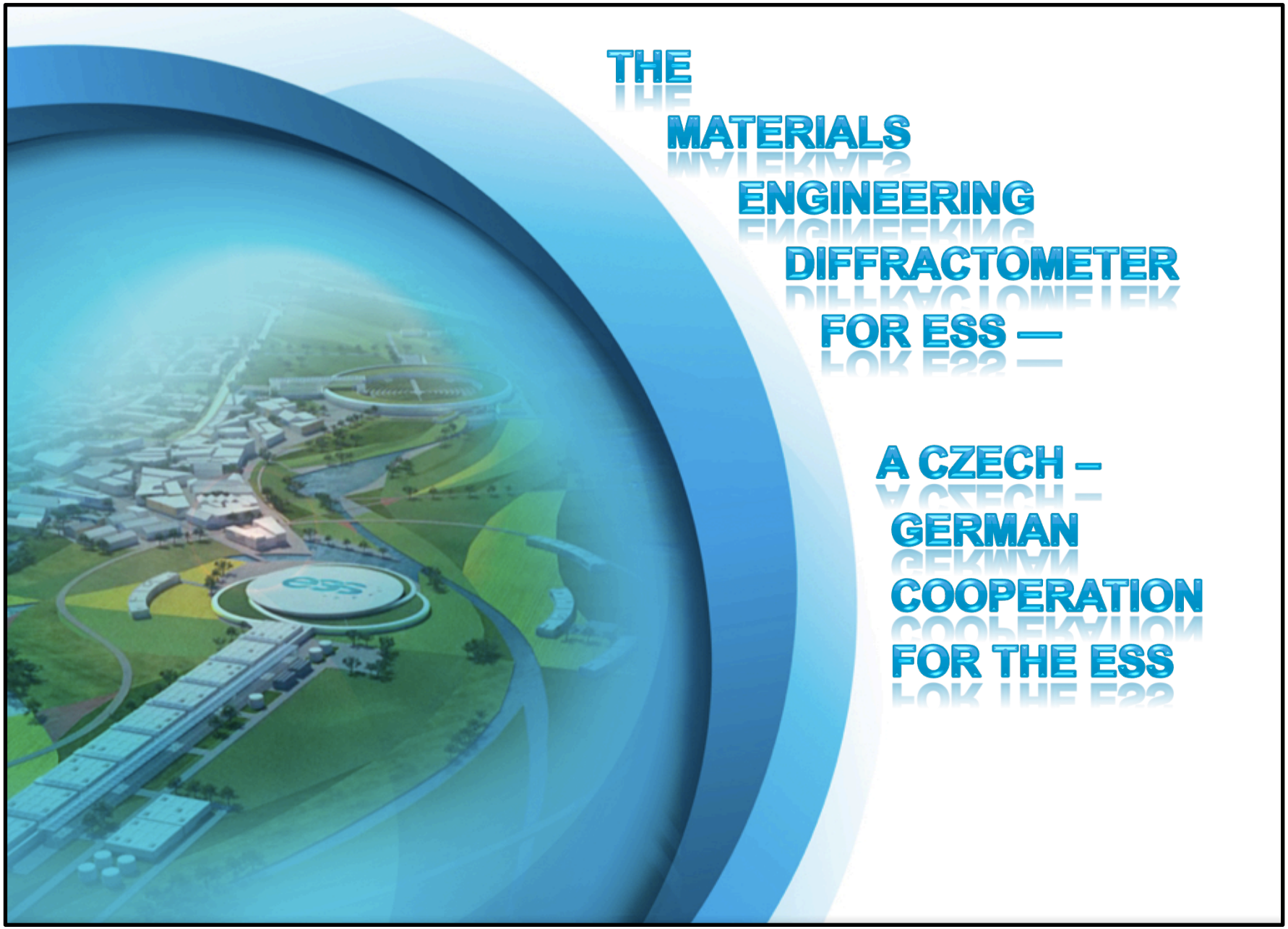
GEMS

Neutrons at FRM II

Photons at DESY

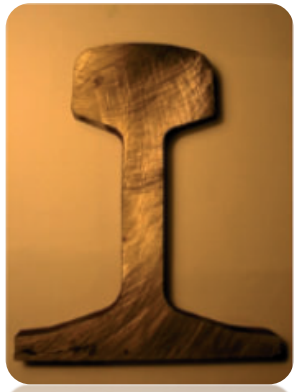
- **infrastructure for complementary research with photons and neutrons in engineering materials science**
- engineering-specific user support
- sample preparation and characterisation labs
- integrated beamtime proposals for photons and neutrons

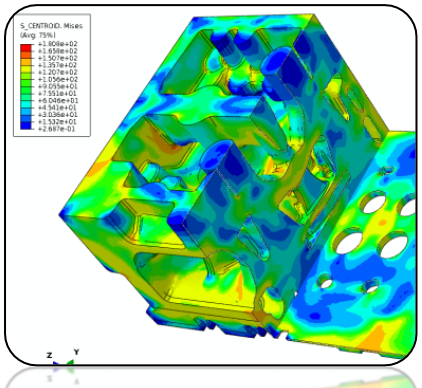
http://gems.hzg.de

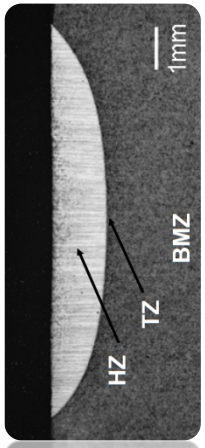

THE
MATERIALS
ENGINEERING
DIFFRACTOMETER
FOR ESS —
A CZECH –
GERMAN
COOPERATION
FOR THE ESS

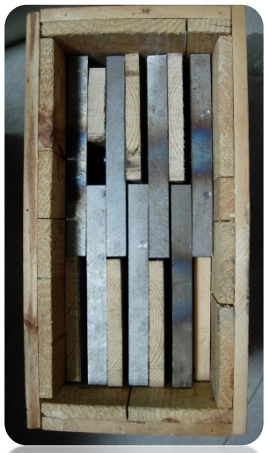
high flux

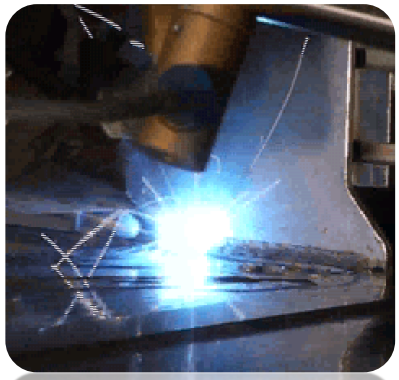
thick specimens	many points	high spatial resolution	many samples	high time resolution
real products	3D strain maps	gradients, surface	process optimization	*in situ* experiments









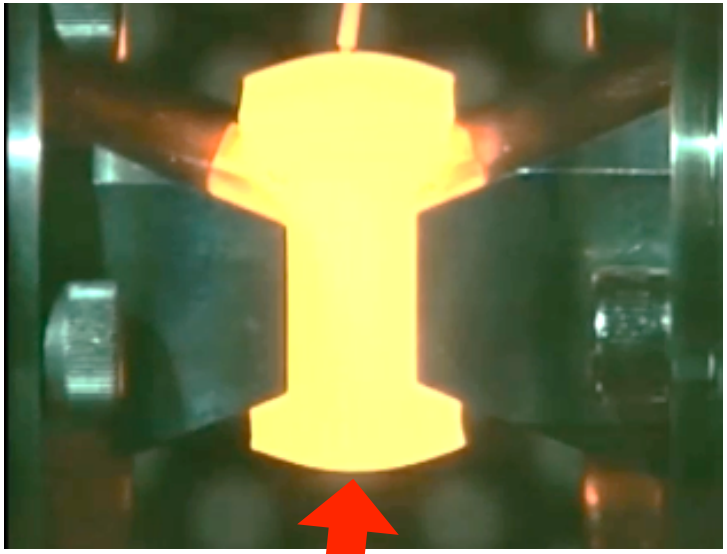


residual stress	texture analysis	*in situ* studies	thermomech simulation	long-term experiments

New *in situ* experiments

Gleeble, a thermo-mechanical simulator:

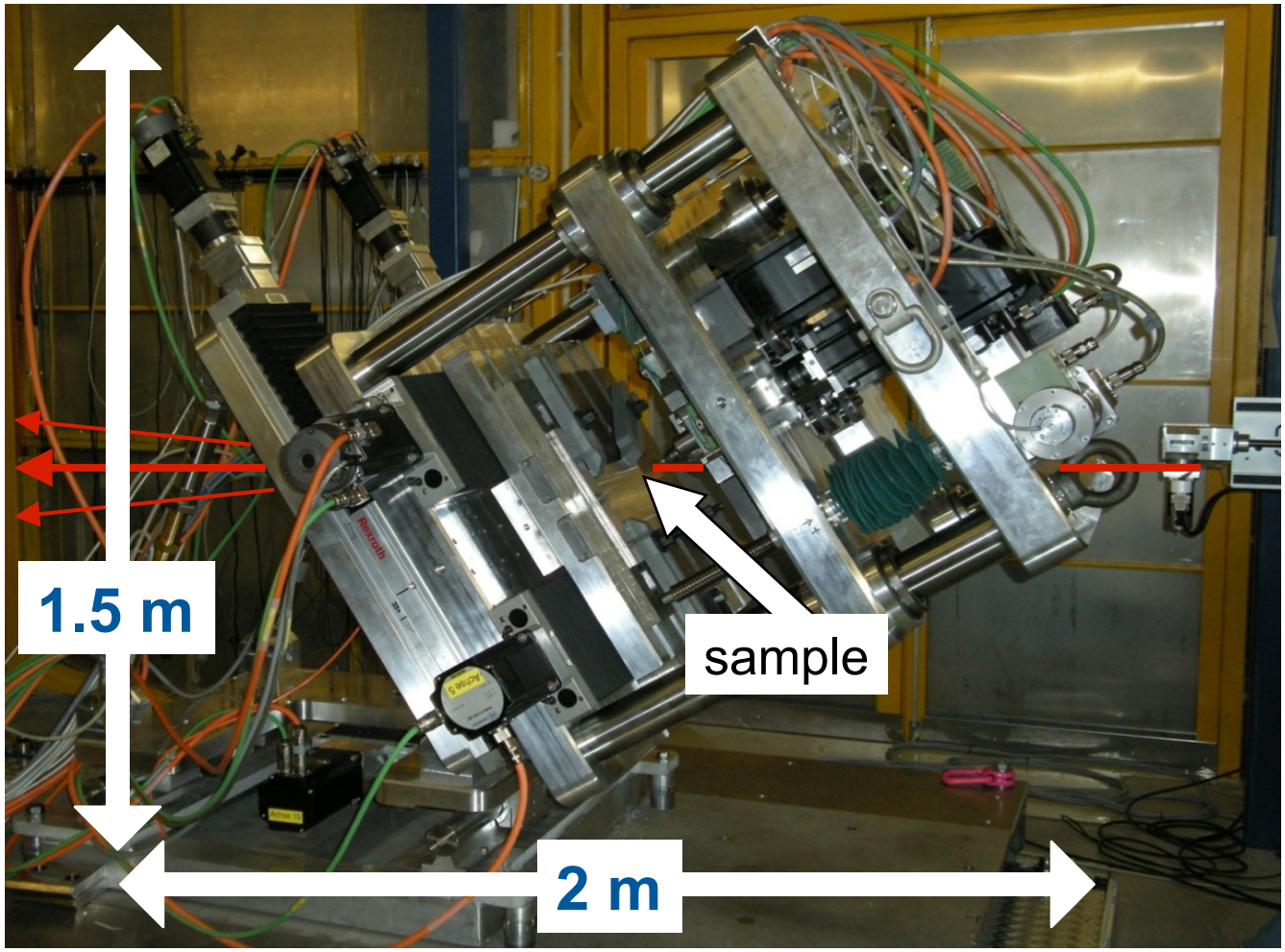
- fast heating and deformation
- study microstructure during **real industrial processes**
- does not yet exist at a neutron instrument,
  first worldwide at the Brazilian synchrotron



Sophisticated user experiments

In situ **studies of the friction stir welding (FSW) process:**

mass:
1400 kg



HZG friction stir welding machine for *in situ* studies
("FlexiStir" used at a HZG synchrotron beamline)

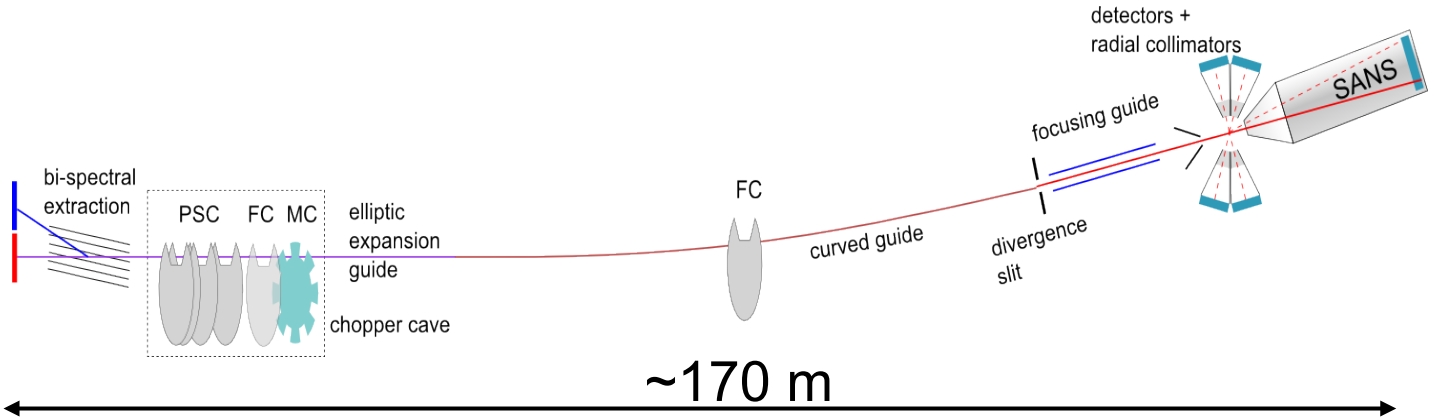
European Spallation Source (ESS)
Lund, Sweden

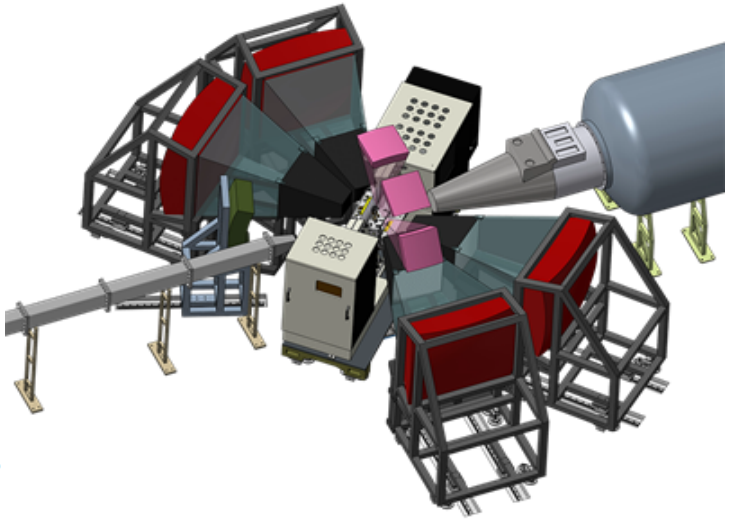
Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research
GEMS
German Engineering Materials Science Centre

Beamline for **E**uropean materials **E**ngineering **R**esearch **(BEER)**

Instrument proposal submitted to European Spallation Source (ESS) 31.10.2013

- Collaboration between HZG (Germany) and NPI (Czech Republic)





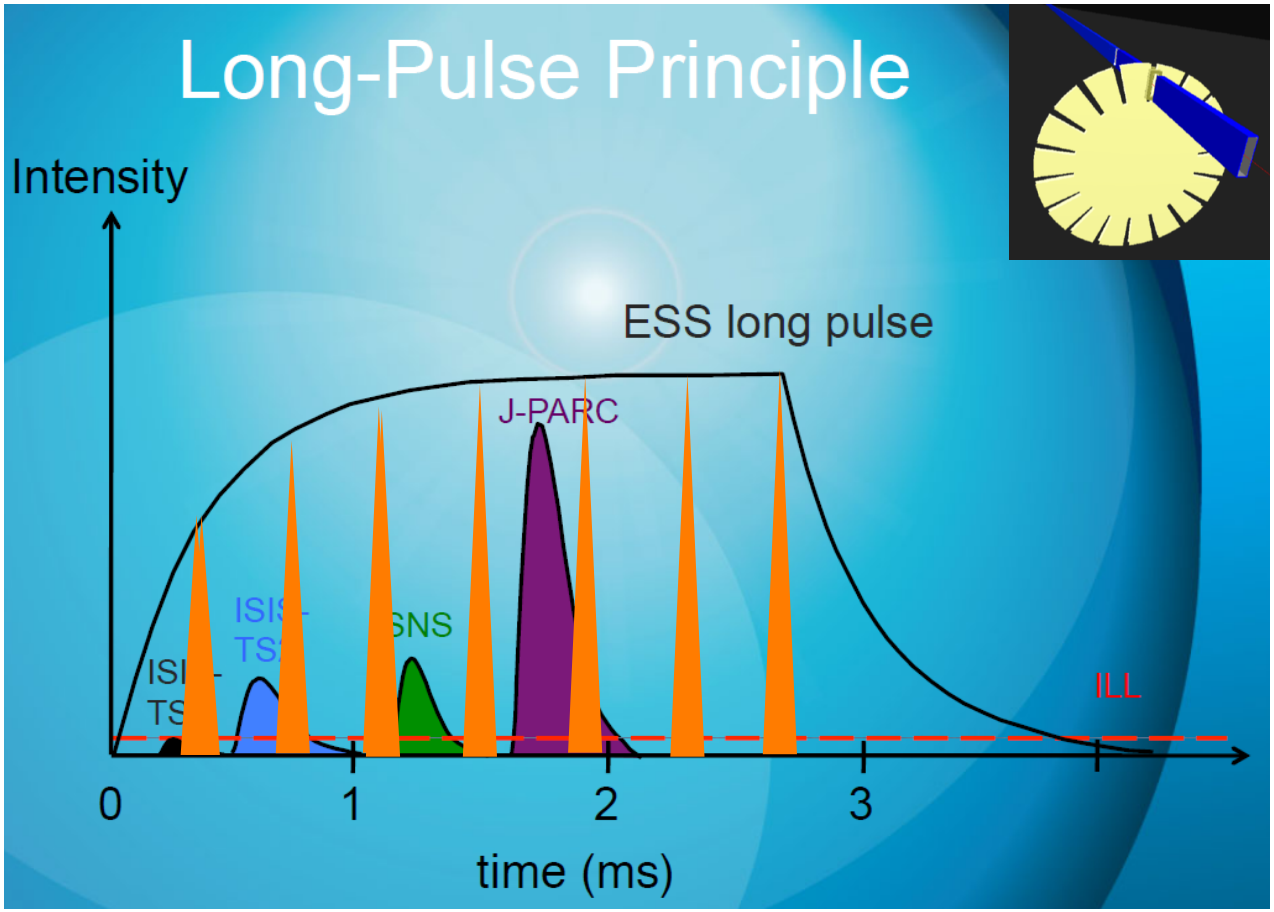
+ high flux, high flexibility, high time resolution

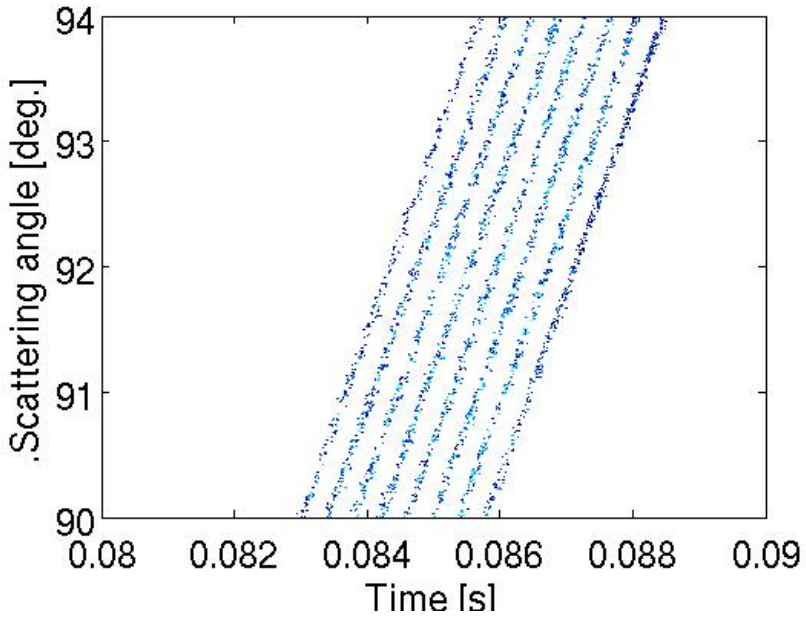
+ novel sample environments

+ combined techniques: Diffraction, Imaging, SANS

→ **Neutron diffractometer optimized for materials engineering research**

Pulse multiplexing by BEER





factor ~ 5–10 gain in count rate

Modulation chopper:
- several well defined wavelengths at the detector
- distinguished by scattering angle

- decouple resolution and intensity
- for well distinguished lines in crystals with high symmetry

potential location of BEER at ESS

Helmholtz-Zentrum Geesthacht
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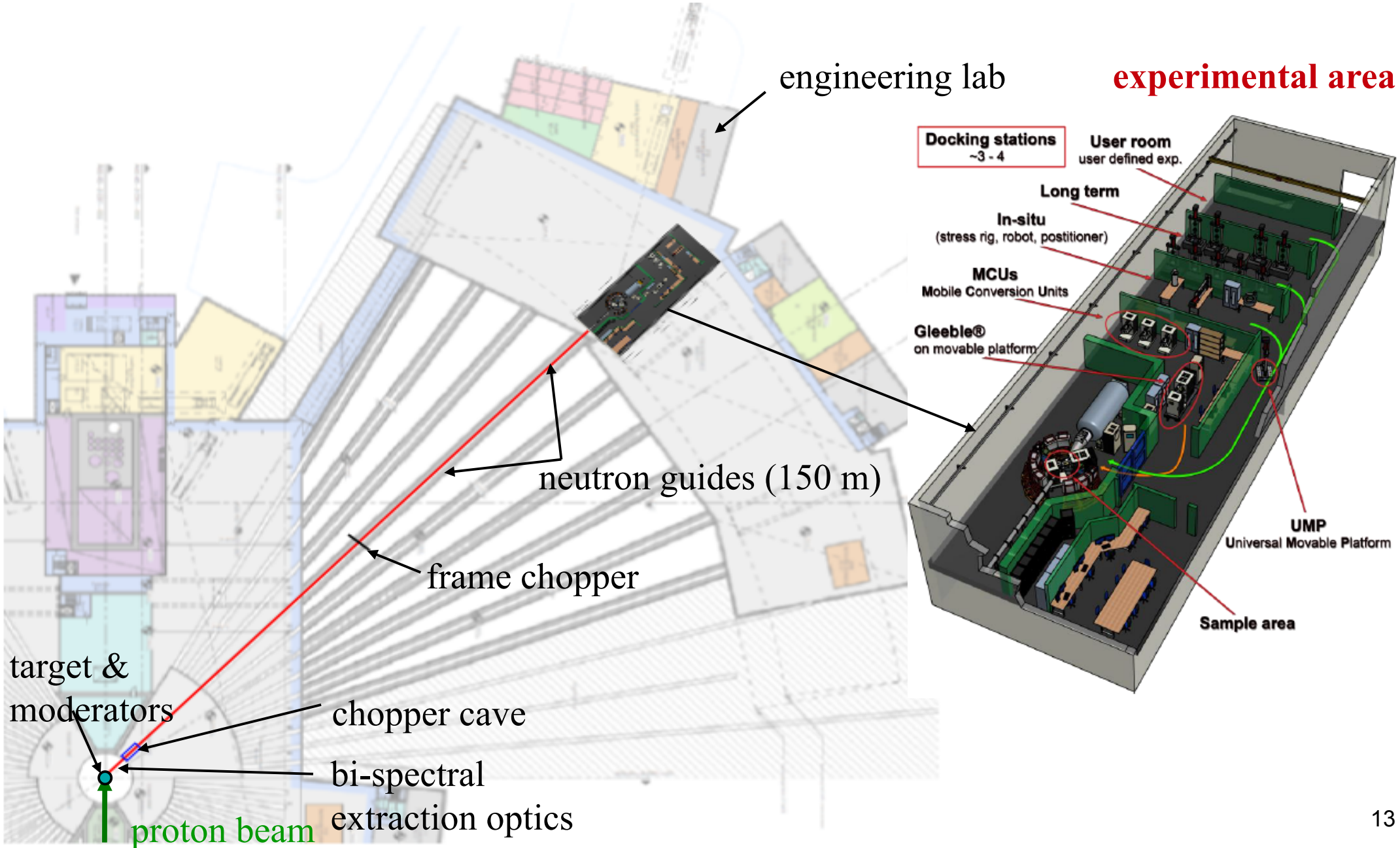


Collaborators

Helmholtz-Zentrum Geesthacht, Germany

H.G. Brokmeier, J. Fenske, R. Kampmann, M. Müller, G. Nowak, M. Ruijaa, P. Staron, A. Schreyer,

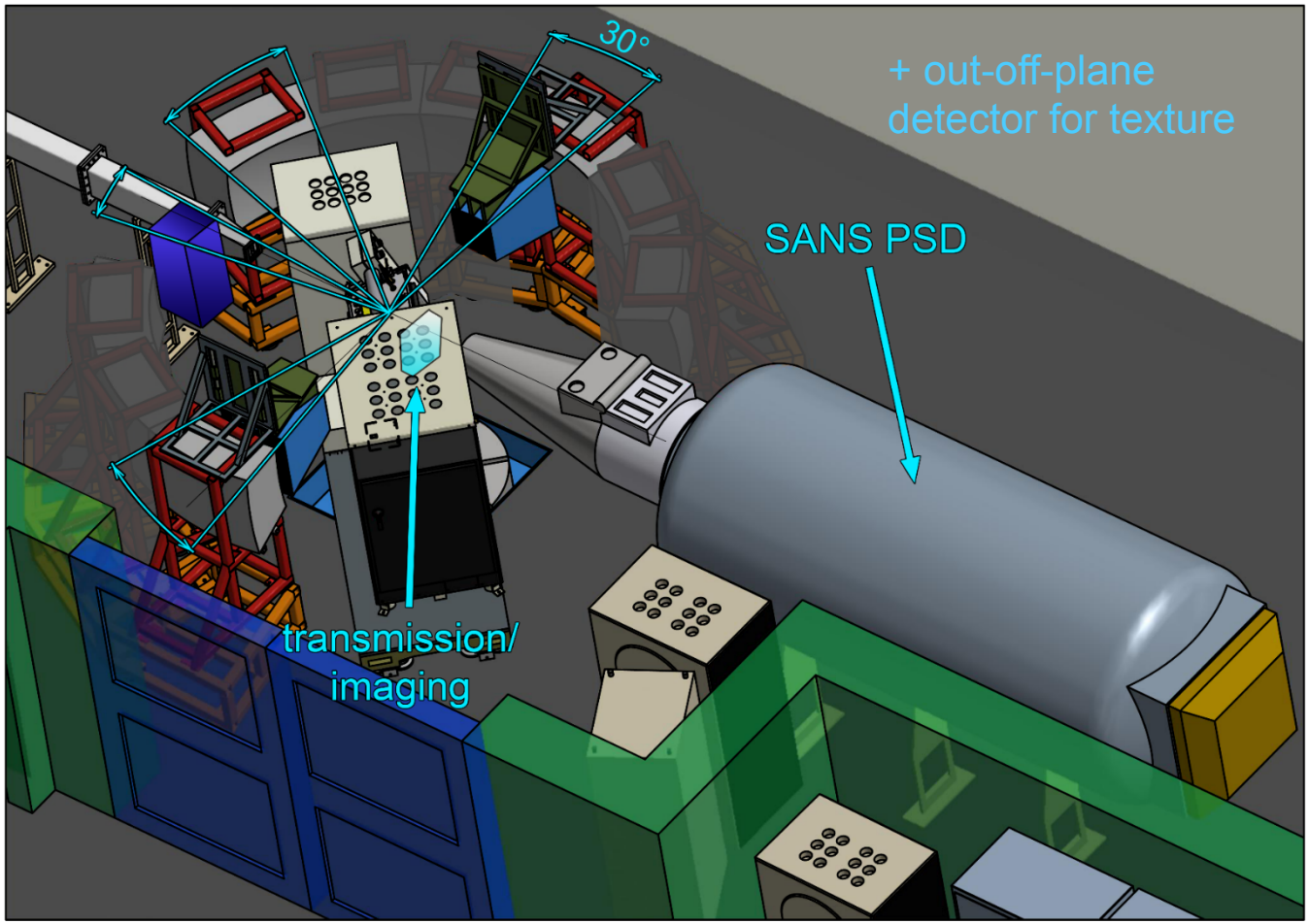
Nuclear Physics Institute, Institute of physics, Czech Republic

P. Beran, L. Kadeřávek, P. Lukáš, P. Mikula, J. Navrátil, J. Pilch, V. Ryukhtin, P. Strunz, J. Šaroun, P. Šittner

European Spallation Source

M. Strobl

Detectors

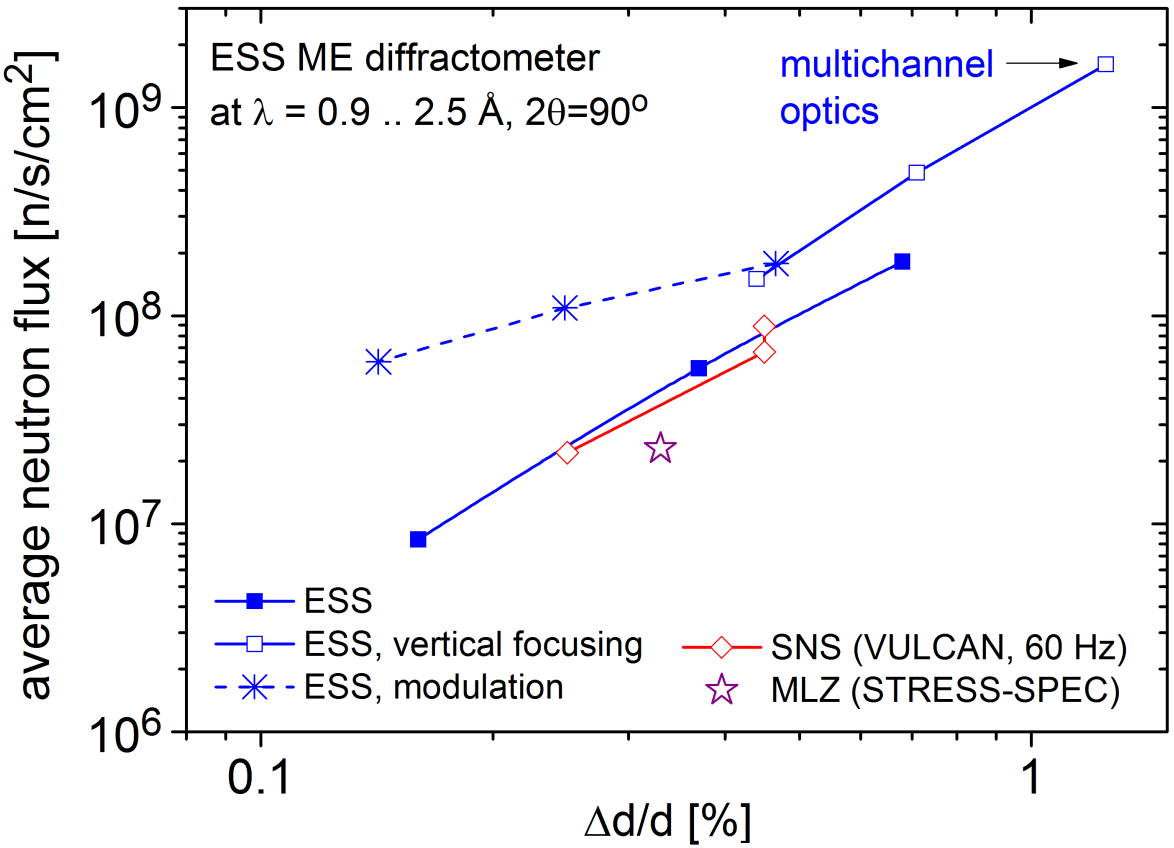


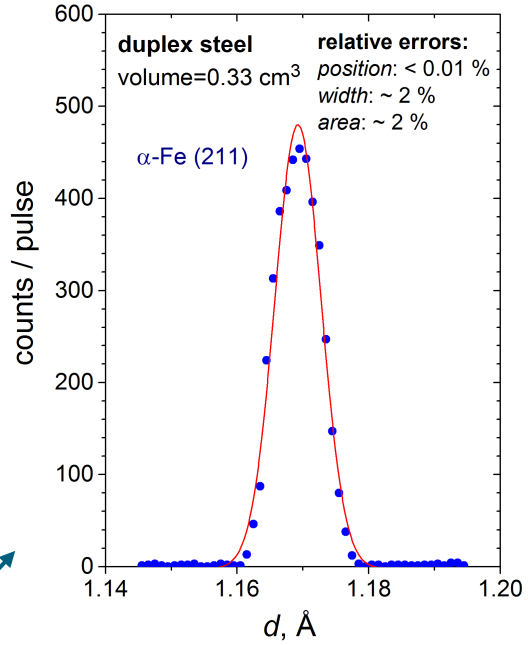
Required parameters
distance: 2 m
resolution: ~ 2 x 5 mm ^{2}

Technology
^{10}B plates
^{3}He (small detectors)

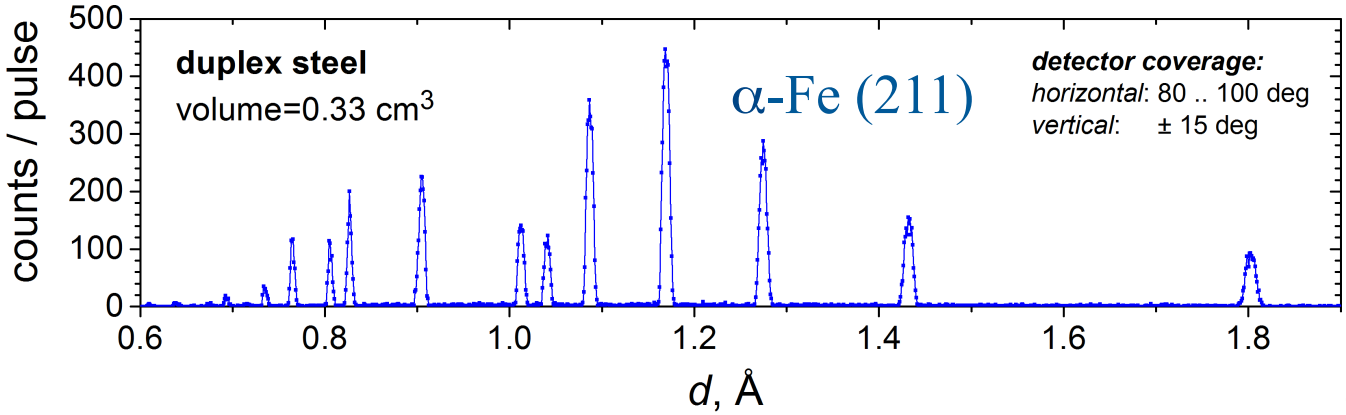
priority:
detectors at 2θ~90^O and 160^O

Instrument characteristics

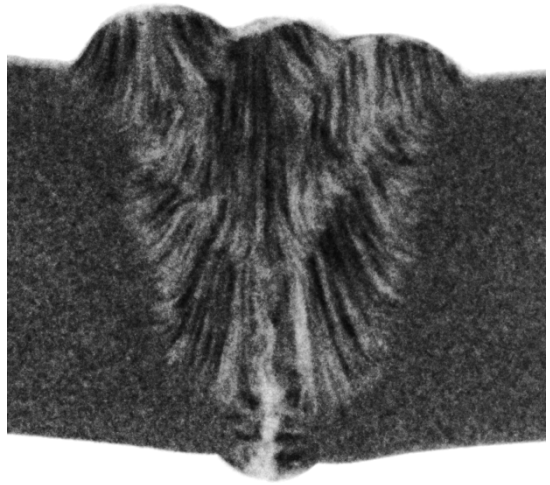




Simulation: data collected in **one pulse**

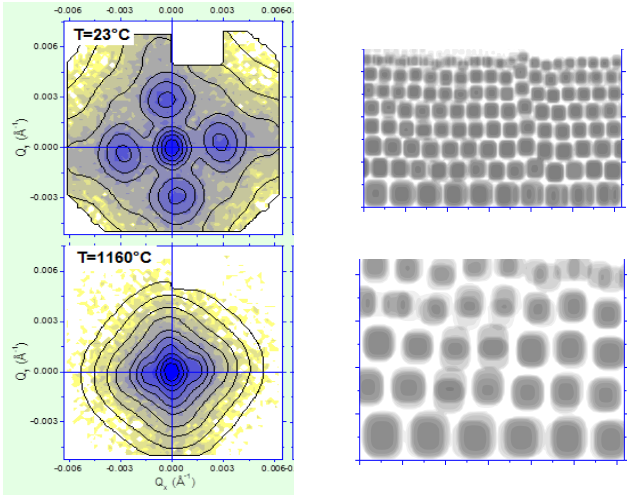


Combining techniques



imaging

simultaneous diffraction and
small-angle scattering (SANS) or imaging
from engineering materials under extreme conditions providing in-situ information on precipitation, void nucleation, crystallization from liquid, sintering at high temperatures and external loads



SANS

Complementarity

Comparison with high-energy X-rays[1]

	Neutrons	HEX-ray
penetration depth	+ + +	+ +
scattering geometry	+ + +	–
beam divergence	+ + +	– – –
intensity	–	+ + +
spatial resolution	–	+ +

=> neutrons are indispensable for residual stress and texture analysis

[1]HEX-rays from a 3rd generation synchrotron source

The need for neutrons:

- Engineering diffractometers in Europe are overbooked

STRESS-SPEC:

year	2009	2010	2011	2012	2013
overbooking factor	2.2*	2.7	1.3*	2.3	1.9

*number only for half year

- Shutdown of BER II in 2020

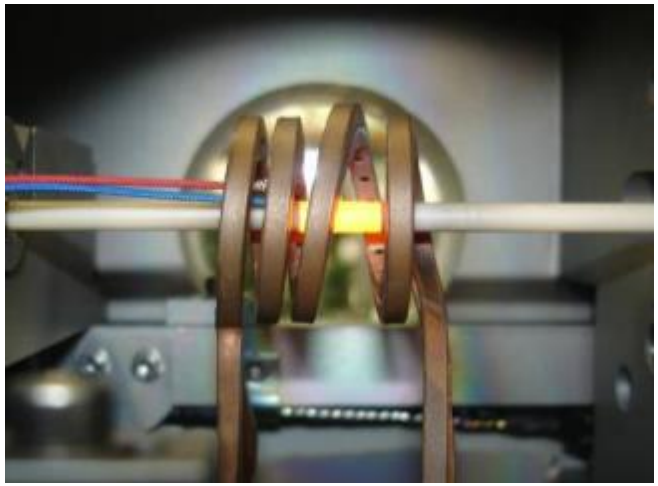
Sample environment

Source: http://www.parmarlabs.com/wp-content/uploads/2012/05/barrel_forging_2009_by_irishmage-d3fo0ud1.jpg

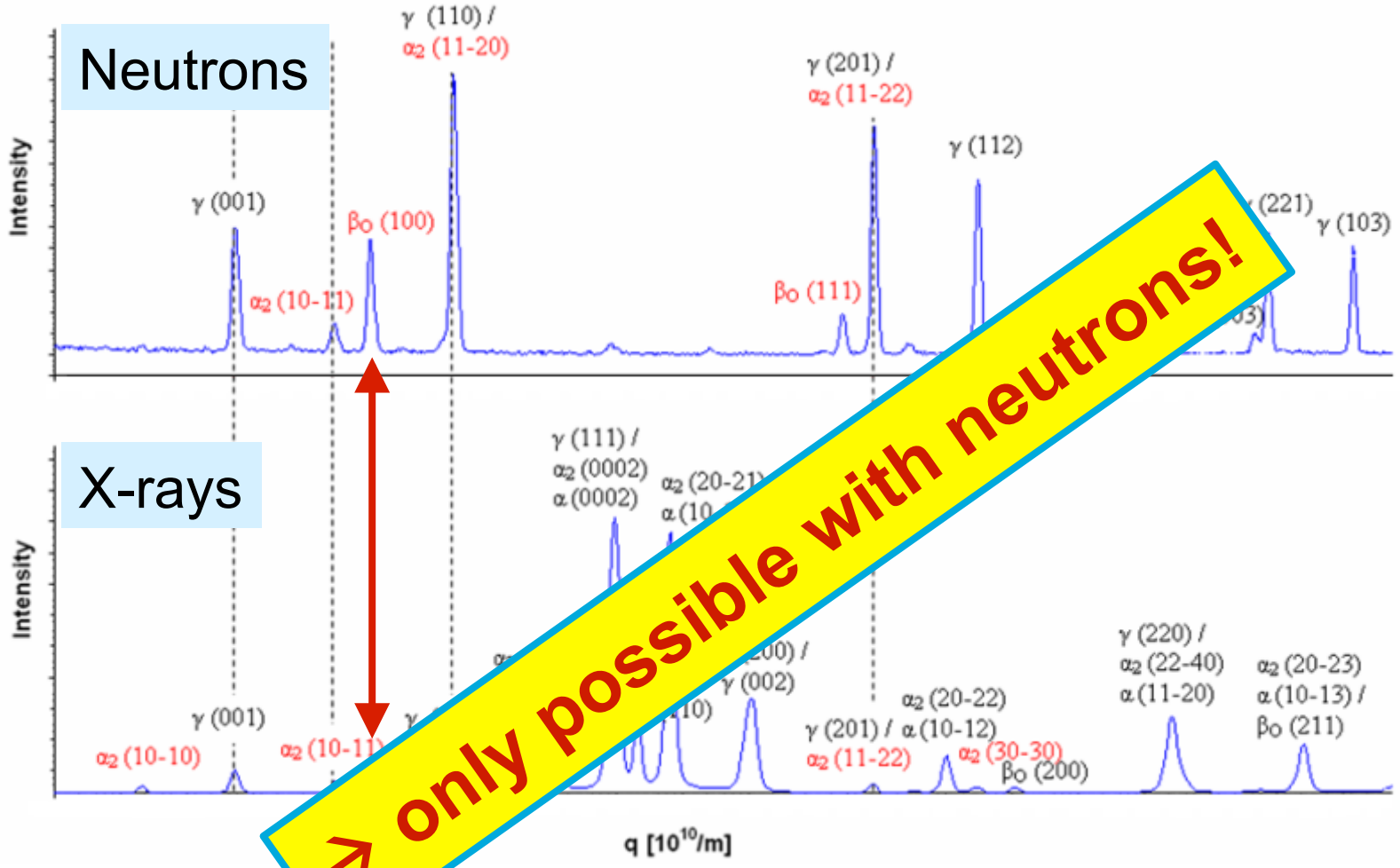
Sample environment

Quenching and deformation dilatometer Bähr 805 A/D for the simulation of thermo-mechanical treatments

- induction heating:
  – max. heating rate 4000 K/s
  – max. cooling rate 2500 K/s
- DSC unit
- deformation units (compr., tension; 25 kN)



Why neutrons?



SPODI@FRM II
λ = 1.55 Å

ID15@ESRF
E = 87 keV
exp. time 12 s

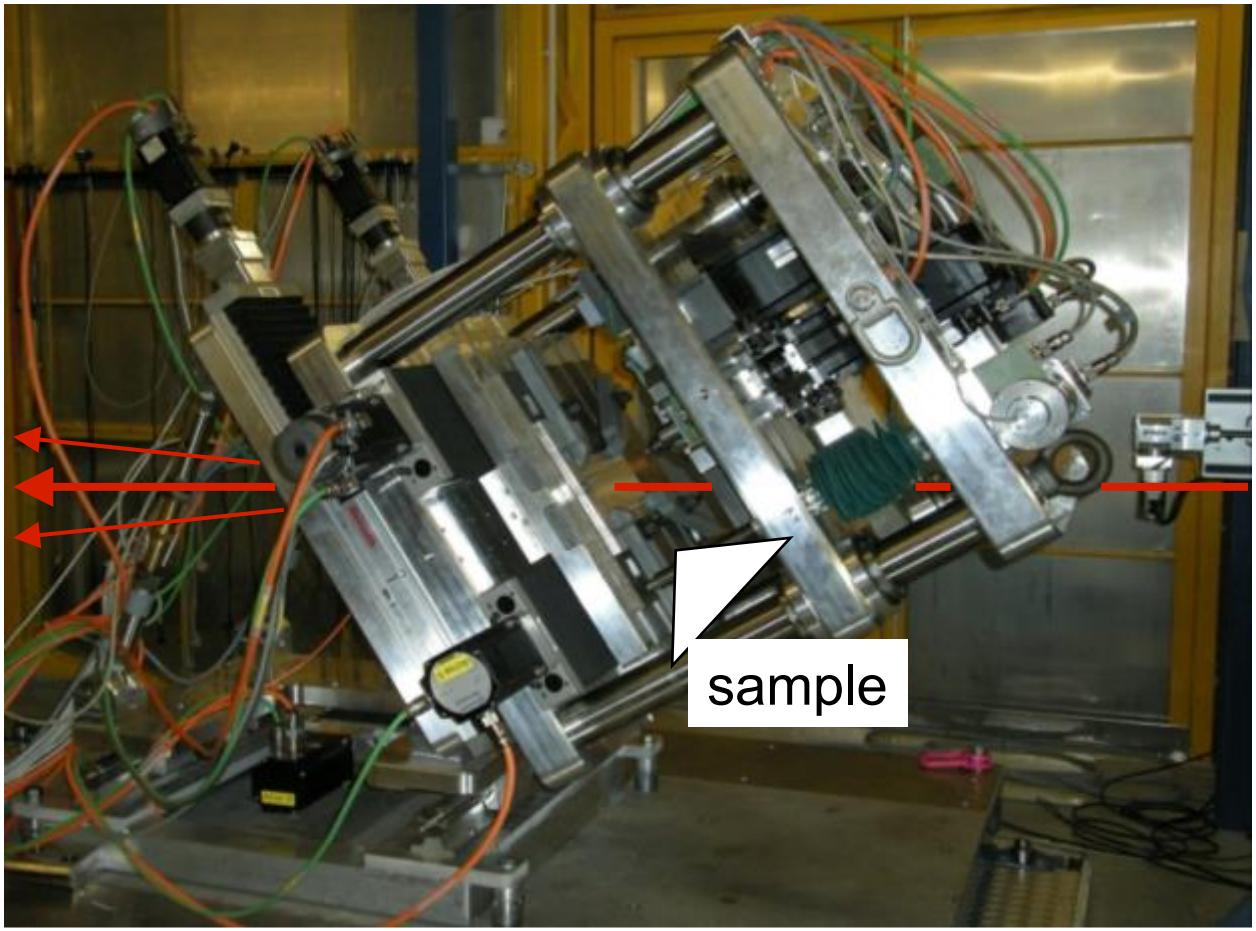
Only neutron allow the study of order–disorder transformations in TiAl alloys, e.g. of the β/β_0-phases. TiAl is a Nullegierung, i.e. b(Ti) = –b(Al)

Source: L. Drössler, *Diplomarbeit*, MU Leoben (2008).

Sample environment

In situ friction stir welding (FSW) experiment

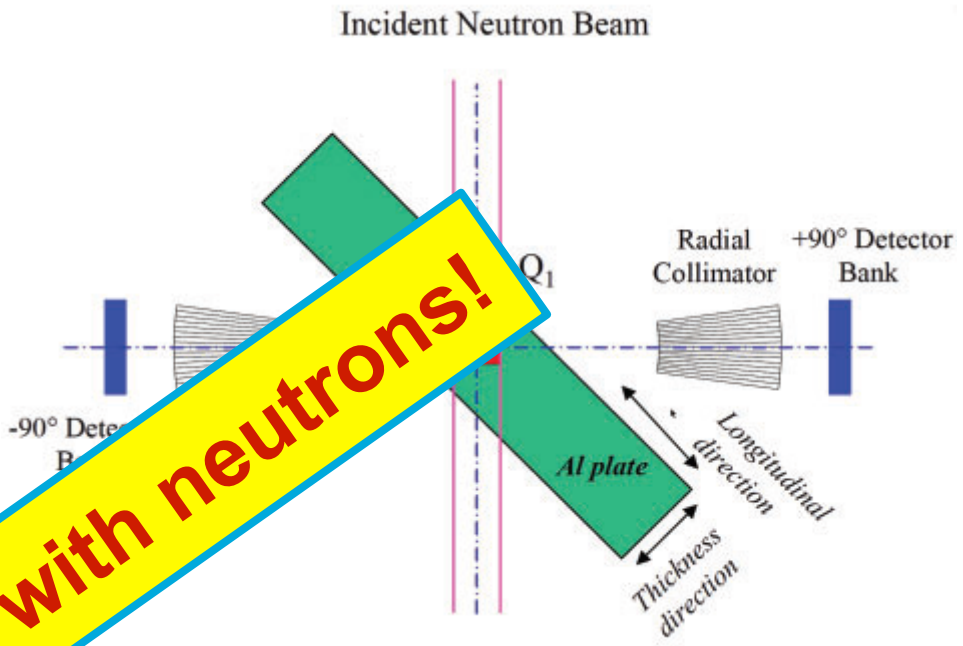
height:
1.5 m
width:
1.2 m
length:
2.0 m
mass:
1.4 t



- **transportable FSW machine**
- **state-of-the-art welding heads**

HZG friction stir welding machine for *in situ* studies ("FlexiStir" used at a synchrotron beamline)

Why neutrons?



→ only possible with neutrons!

First in situ friction stir welding experiment with neutrons at SMARTS@LANSCE

→ residual stress analysis

W. Woo, Z. Feng, X.-L. Wang, D.W. Brown, B. Clausen, K. An, H. Choo, C.R. Hubbard, S.A. David, Sci. and Technol. Weld. Join. 12 (2007) 298–303.