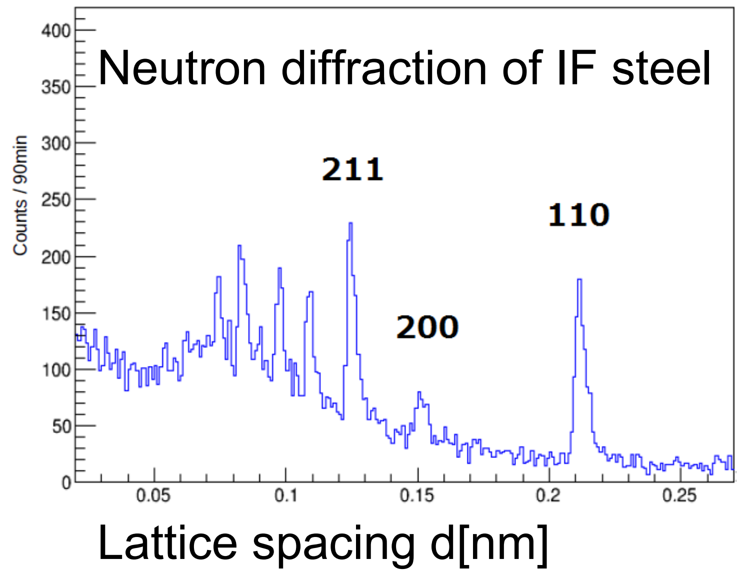
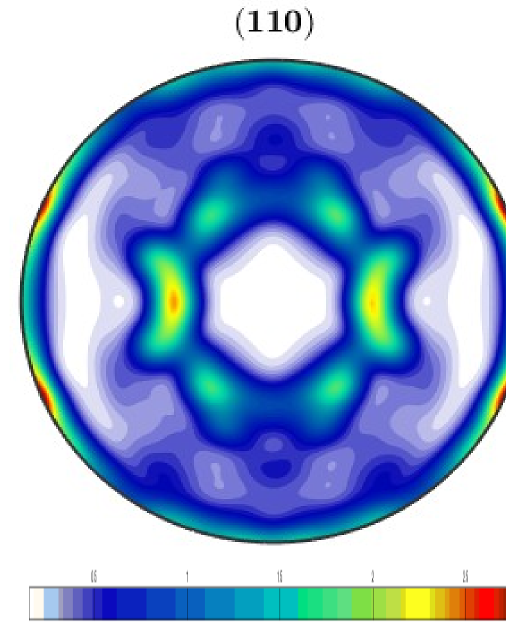
Measurement of neutron diffraction with compact neutron source RANS



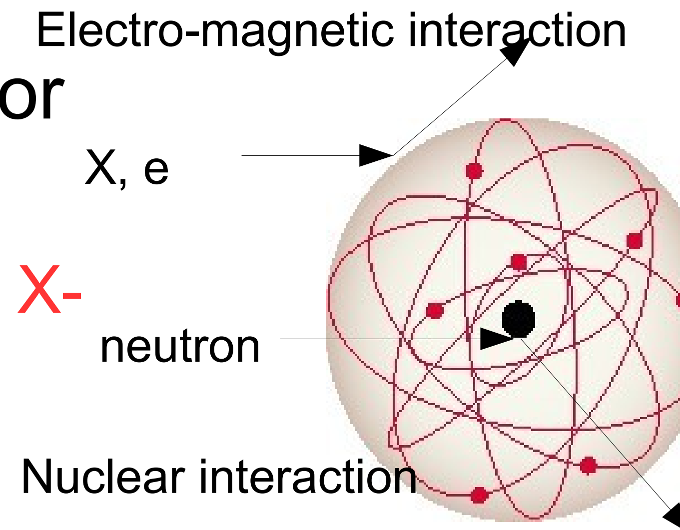


Y.Ikeda, M.Takamura, A.Taketani, H.Sunaga, Y.Otake, Y.Suzuki, M.Kumagai, Y.Oba, T.Hama

Compact neutron source

- Neutron has a long mean free path for heavy ion
  - ~1cm for neutron in iron.（nm~μm for X-ray or electron）
  - Sample polishing unnecessary
  - Measureable during deformation
- Measureable for light ion (water)
- Many neutron sources were large
- “Compact” neutron source
  - Easy experiment in a labor
  - Low flux（$\sim 10^{-4}$）

→**how much it can do**

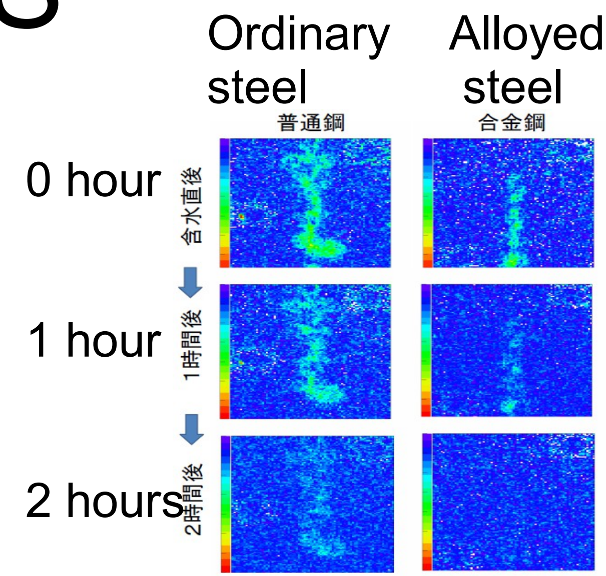


J-PARC synchrotron 0.5km

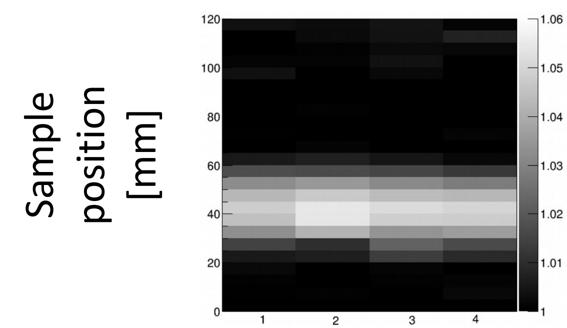
RANS : Riken. Accelerator-driven compact Neutron Source ~15m

Studies in RANS

- Study of the corrosion mechanism
  - Three-dimensional image of internal corrosion and water behavior under steel coating.
- Infrastructure preventive maintenance
  - Measurement of rebar, gap and water in bridges
  - Development of portable neutron source
- Measurement of crystal structure(2014 new!)
  - Measurement of a texture of an steel sheet
  - Pole figure of the texture
  - Capture the change of texture due to the deformation
  - Measurement of austenite volume



Water behavior in steel



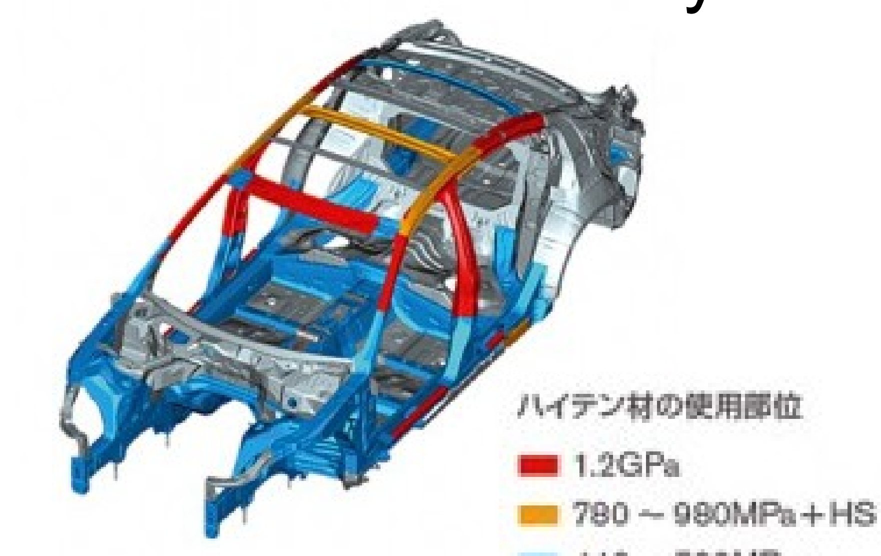
Gap of φ18 mm in concrete of 300 mm

Expectations for high tensile strength steel

Material	Strength/ weight ratio ($kNmkg^{-1}$)	Cost $\$kg^{-1}$
high tensile strength steel	60~190	~1
Al alloy (A6061)	115	~5
Mg alloy (AZ31)	137	~30
CFRP (AS4)	4300	~30

http://plast.me.tut.ac.jp/
http://www.yano.co.jp/press/pdf/1302.pdf

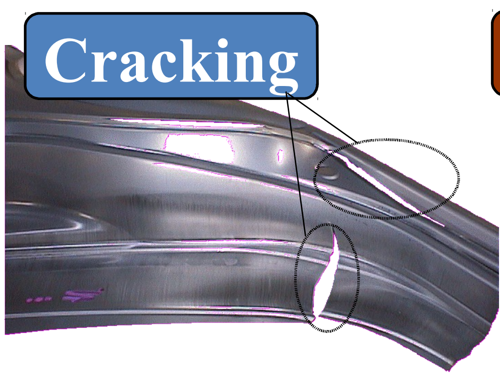
- High specific strength with low price
  - 10% weight reduction =10% of improvement of fuel efficiency



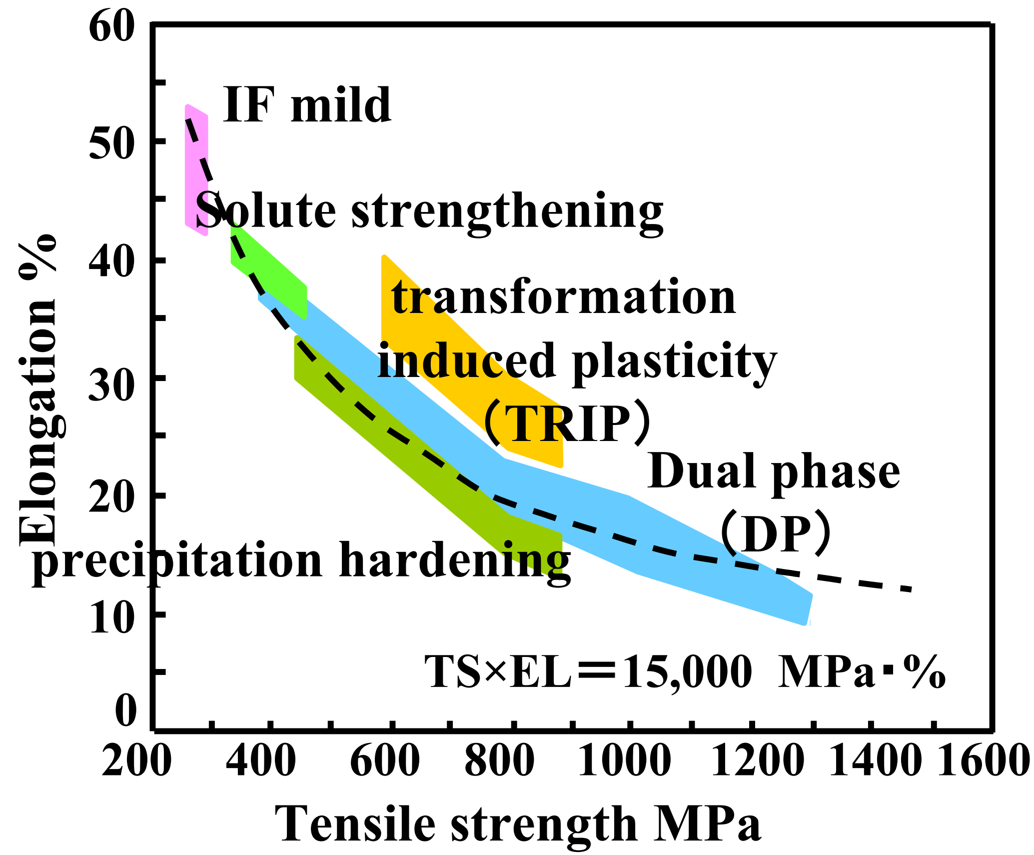
Nissan

Strength and Formability

- High-strength steel has a poor formability
  - Low forming limit or spring back in stamping operation

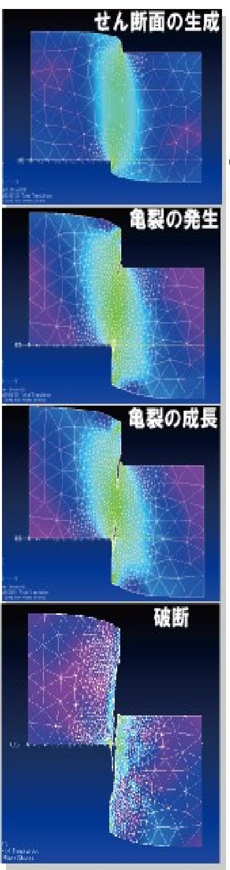


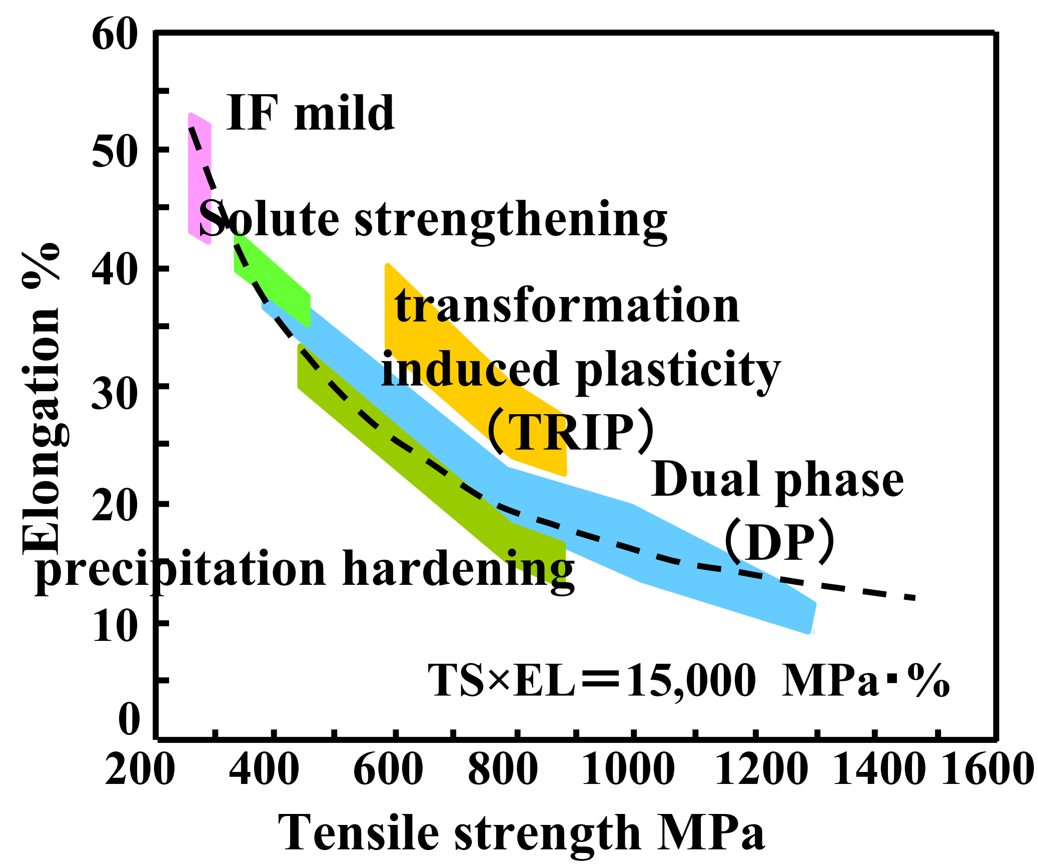
Formability and strength is in the inverse relationship



The plastic deformation and material development

- New material development
  - Establish both strength and formability
  - Elucidation of crystallographic nature
  - Use of austenite
- Understanding the plastic deformation mechanism of material
  - Sophistication of simulation of plastic deformation
  - Crystal plasticity calculations (mesoscopic)

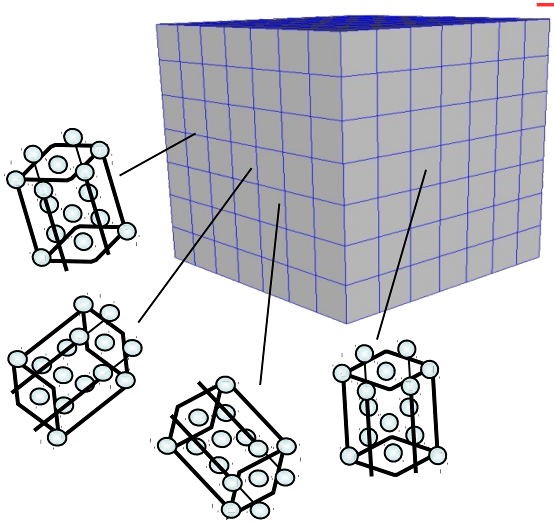


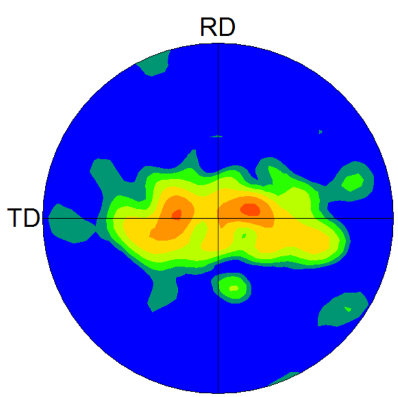


Crystal plasticity analysis

- The macroscopic deformation characteristics are calculated with mesoscopic plastic deformation.
  - Anisotropy of texture and mechanical property are considerated
  - Crystal texture that is changed by plastic deformation should be measured for the calculation

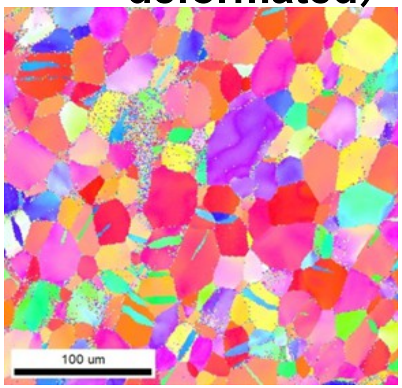
→measurement with RANS



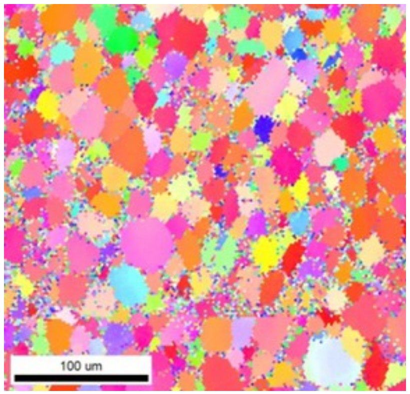


Ti textures

(compressive deformated)

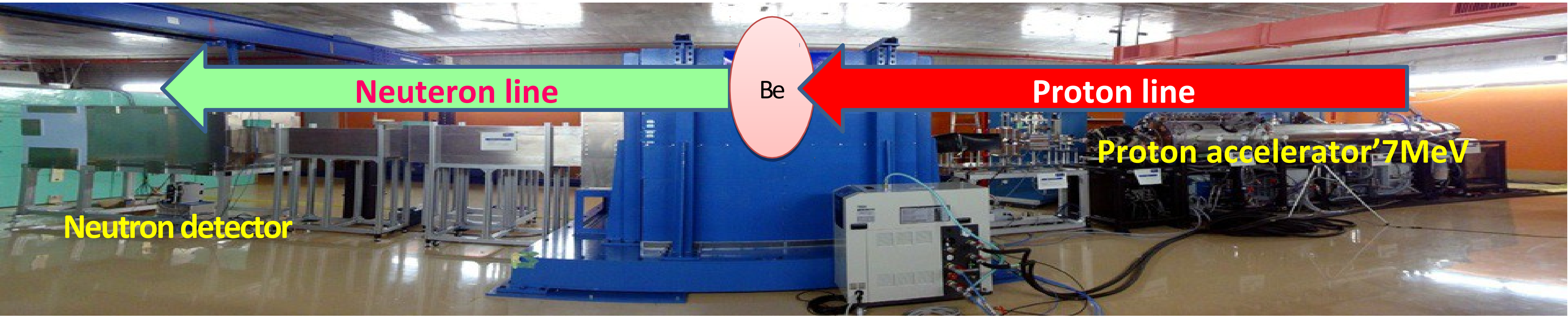


（undeformed）

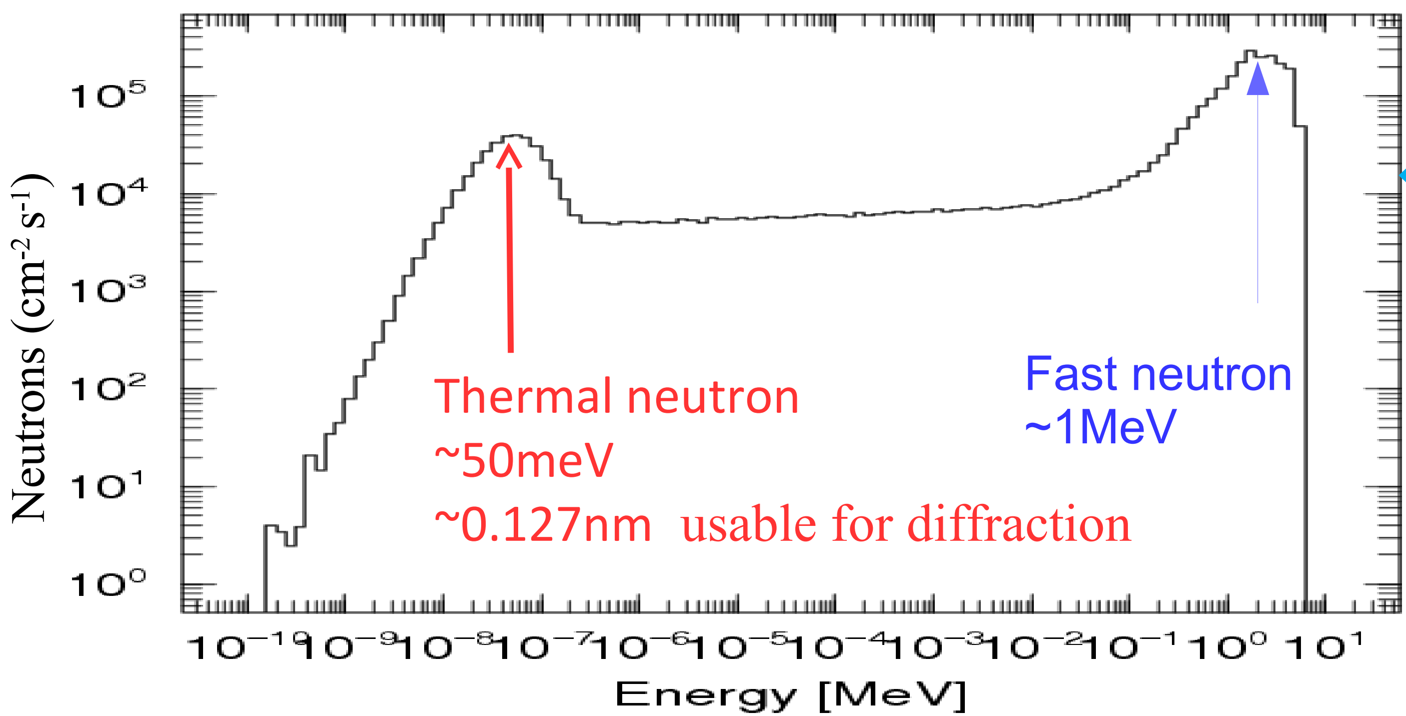


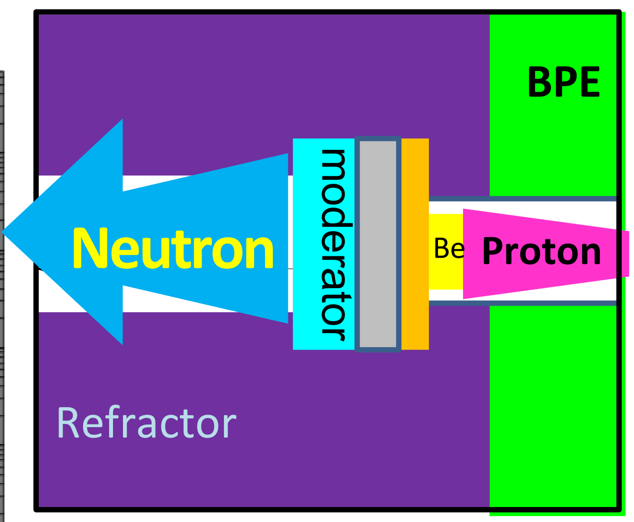
Pictures made by Prof.Hama

RANS neutron spectra

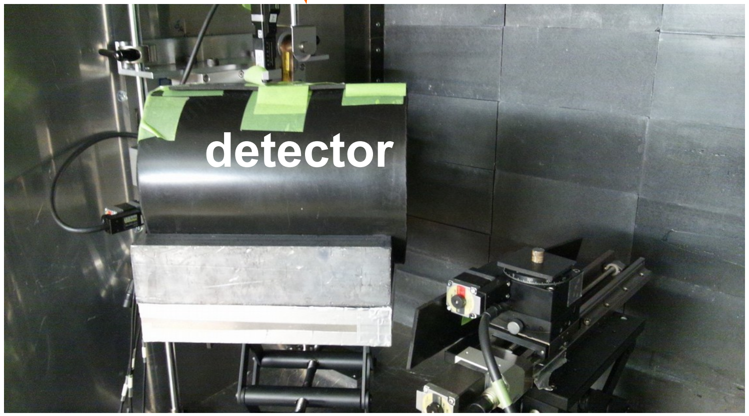


- simulation Dr.Wang



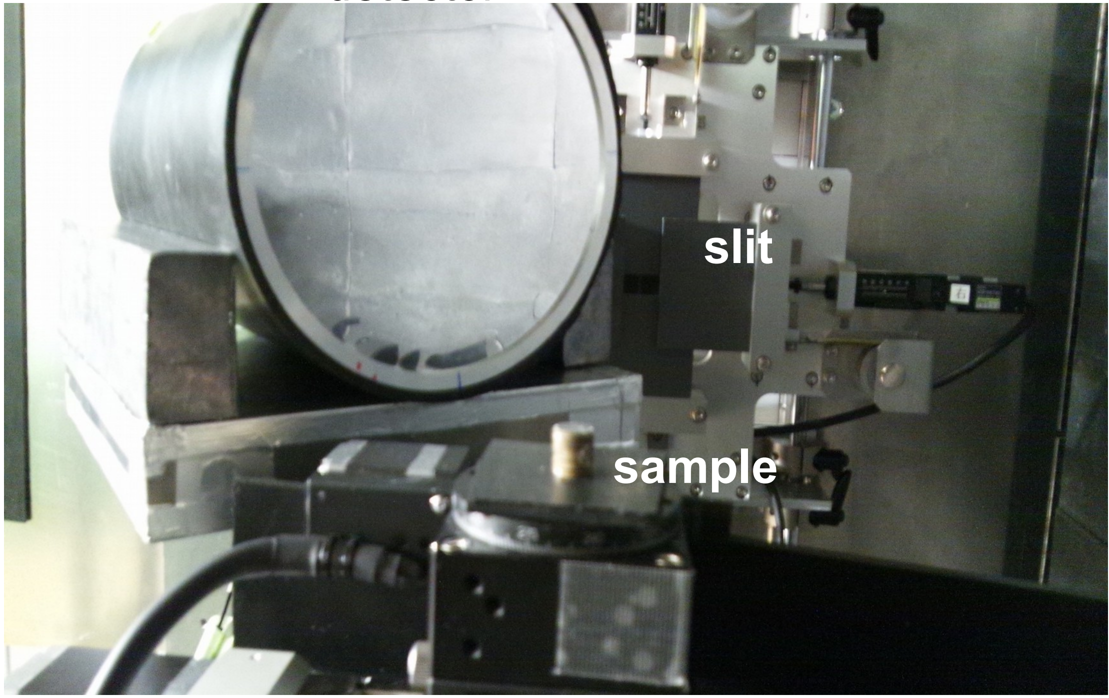


Diffraction experiment in RANS



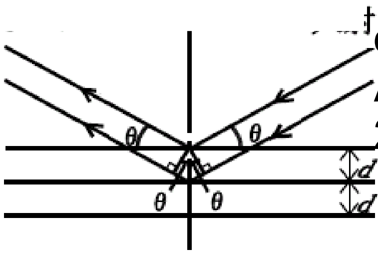
Detector is located closed to sample to increase the statistic. ~15cm

detector



Turn table

Resolution and statistic of diffraction peak



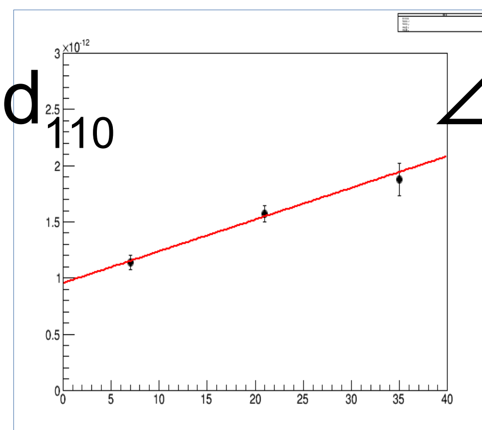
d:Lattice spacing
λ:wave length
2θ:diffraction angle

$$d = \frac{\lambda}{2\sin\theta}$$

Large θ reduce ⊿d/d

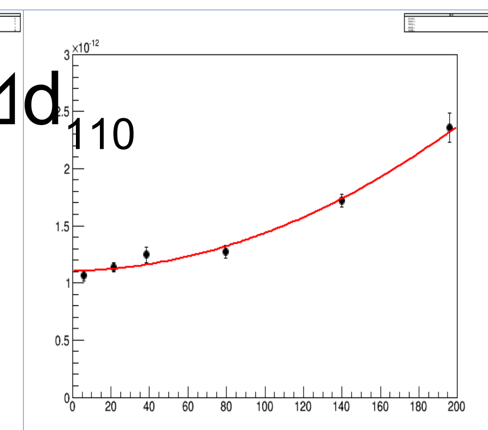
Maximum luminosity when 150us of proton pulse
Half when 20us, with 2 times of resolution

⊿d 110



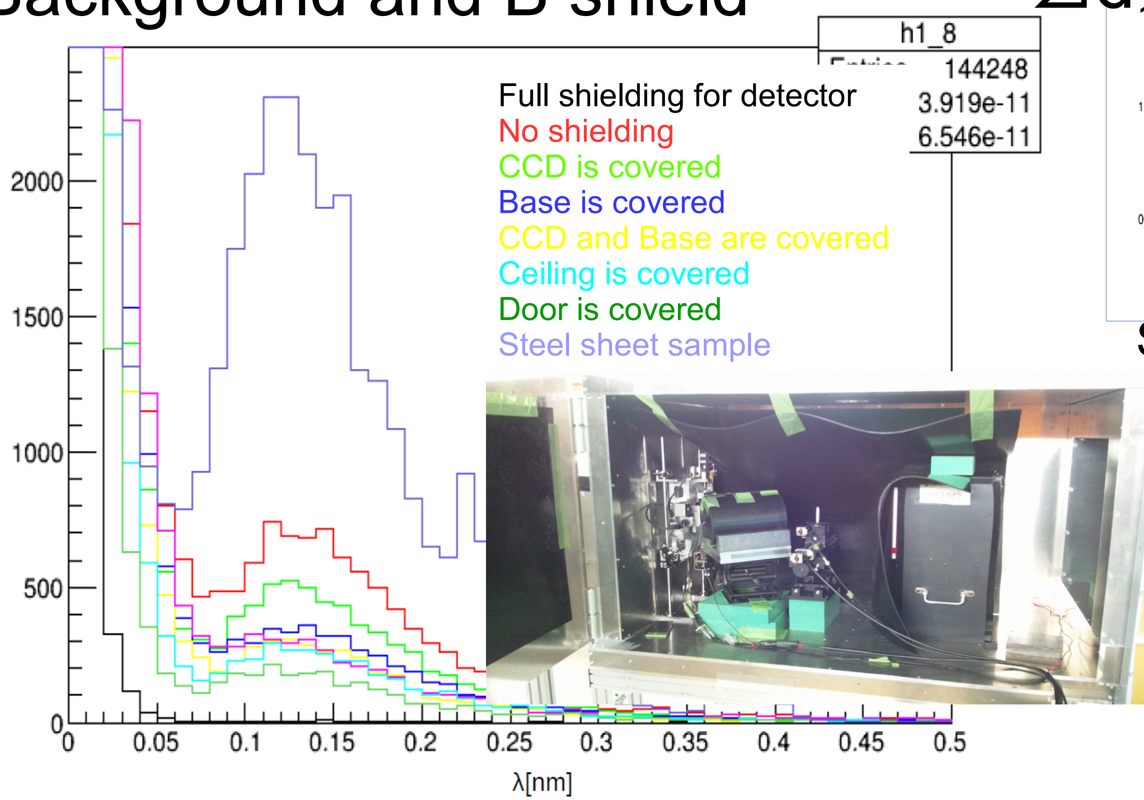
Sample size Z[mm]

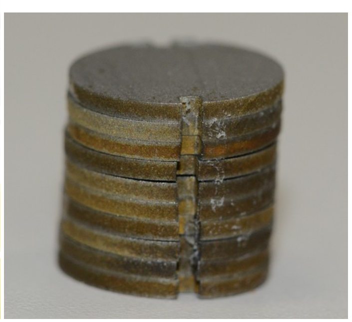
⊿d 110



Proton pulse width[us]

Background and B shield



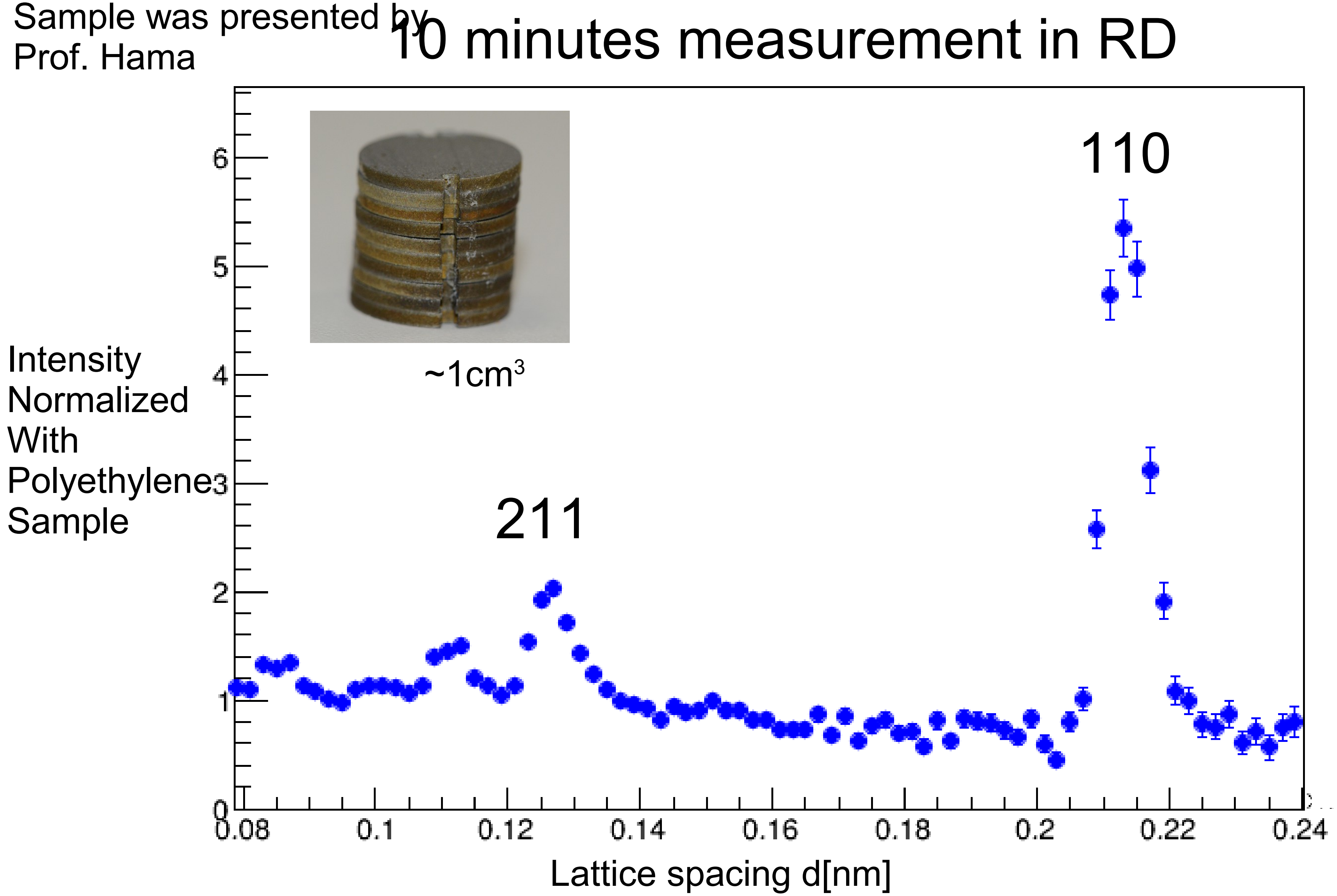


~1cm^3

Small sample reduces statistic.
Large sample reduces resolution

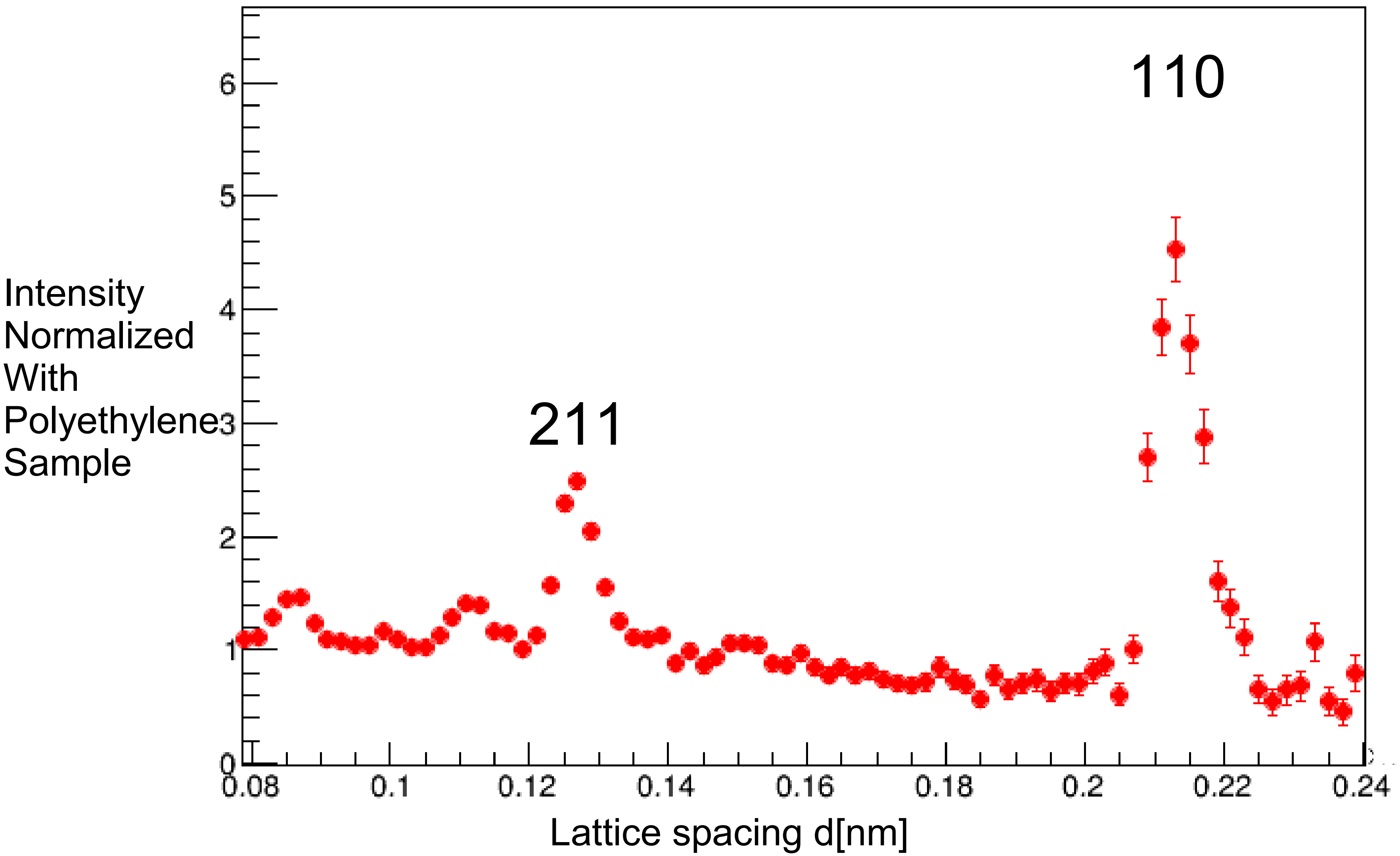
Measured diffraction peaks in RANS (undeformed IF steel)

Sample was presented by Prof. Hama



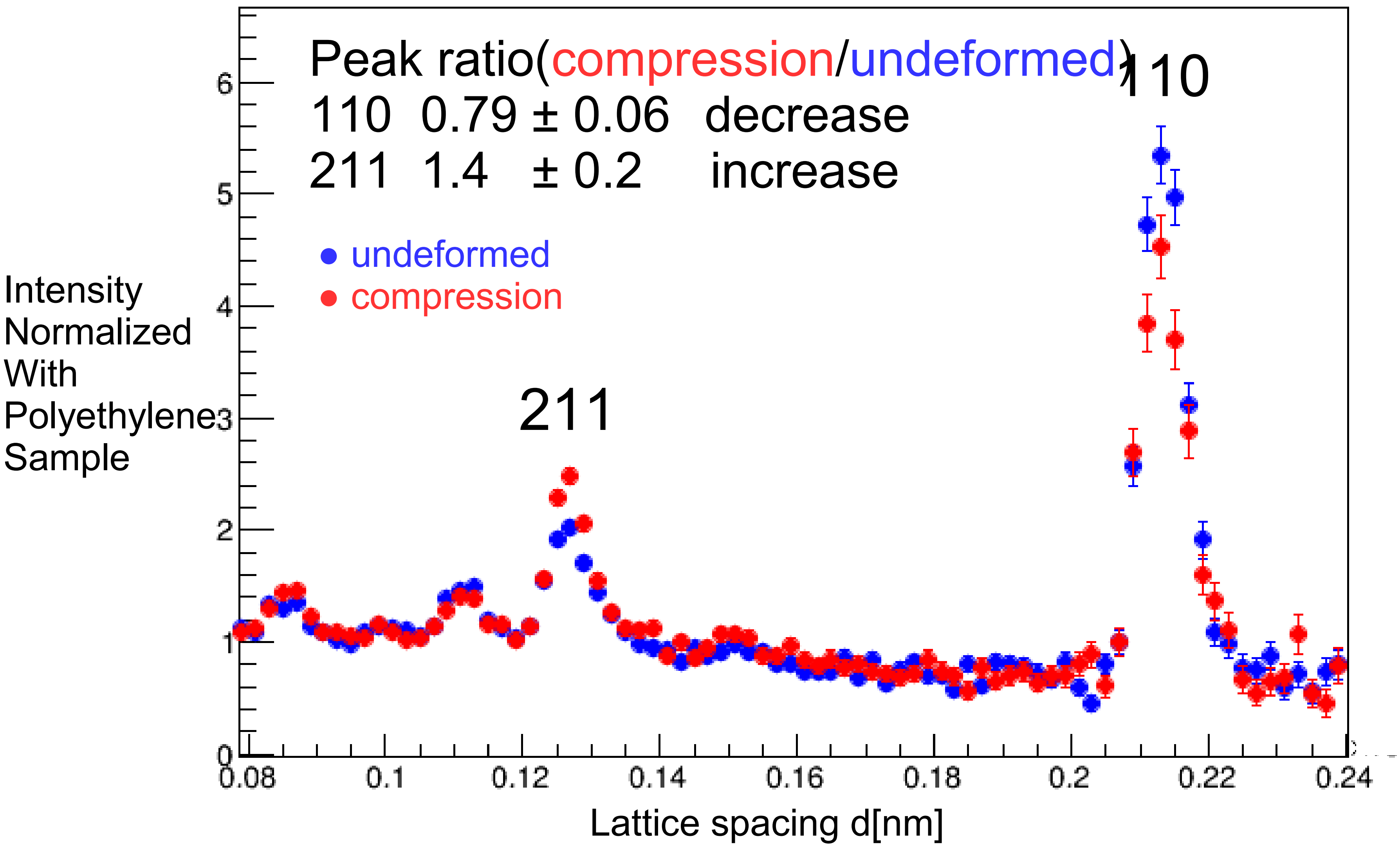
Measured diffraction peaks in RANS
(IF steel with 10% compression)

10 minutes measurement in RD

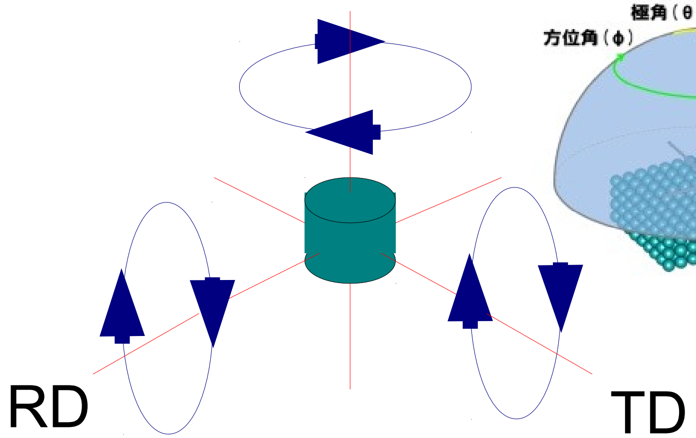


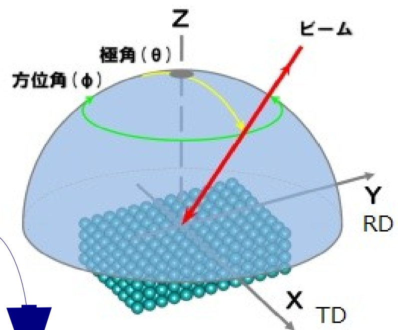
Change in diffraction peaks with deformation

10 minutes measurement in RD

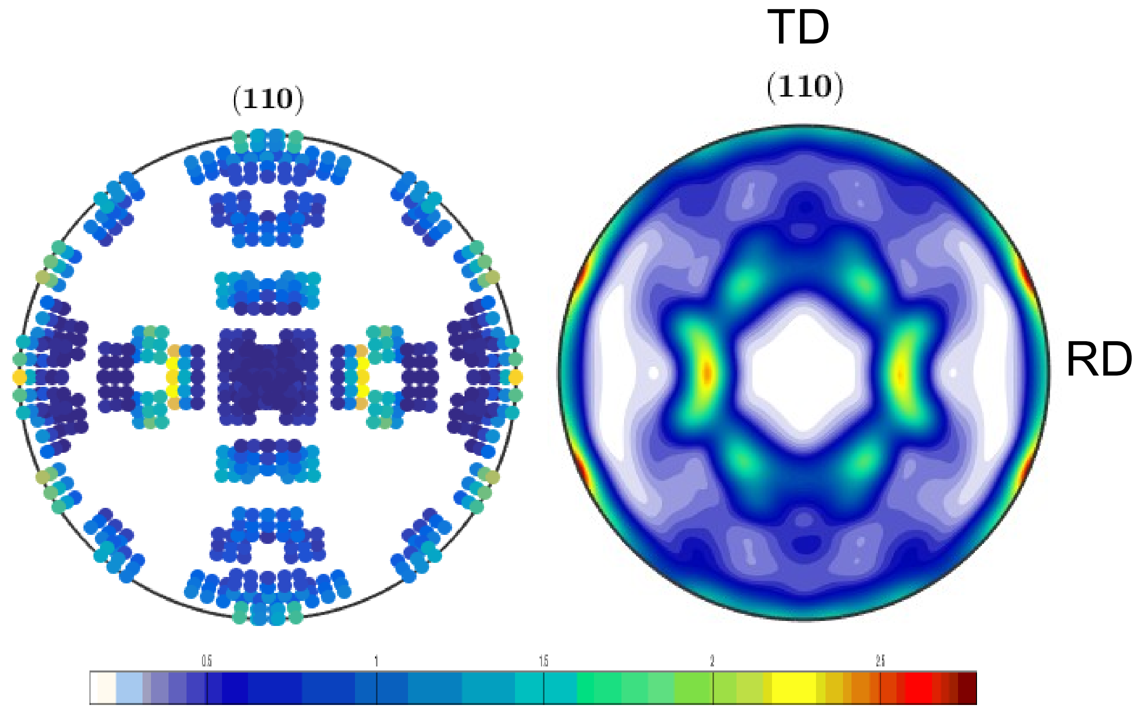


pole figure



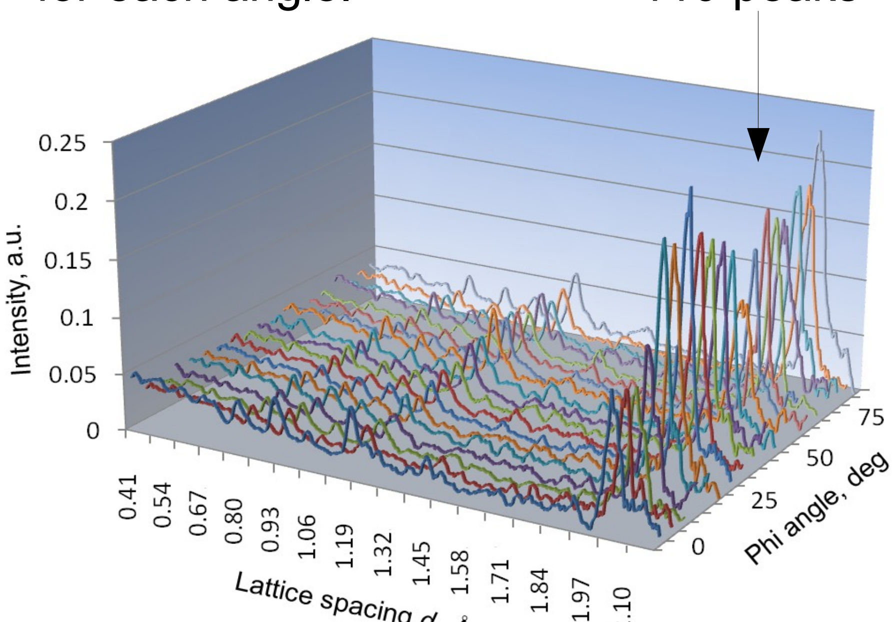


Anisotropy of texture is measured



Diffraction peak is measured
for each angle.

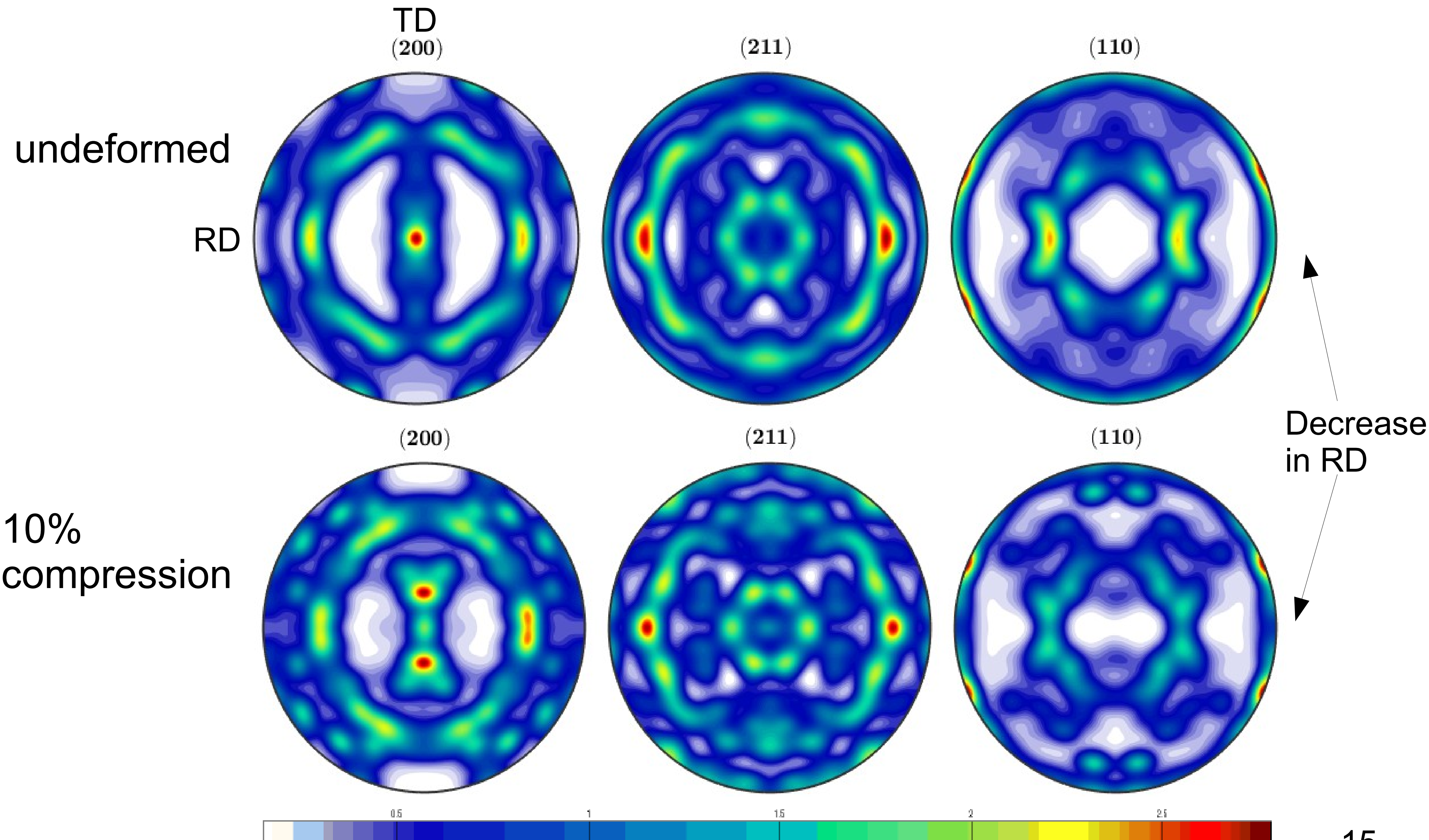
110 peaks



Presented by Dr.Suzuki

21 diffraction measurements
covered a quarter of pole figure.
It is complemented with ODF
（mtex-4.0.12）

Pole figure by neutron and X-ray



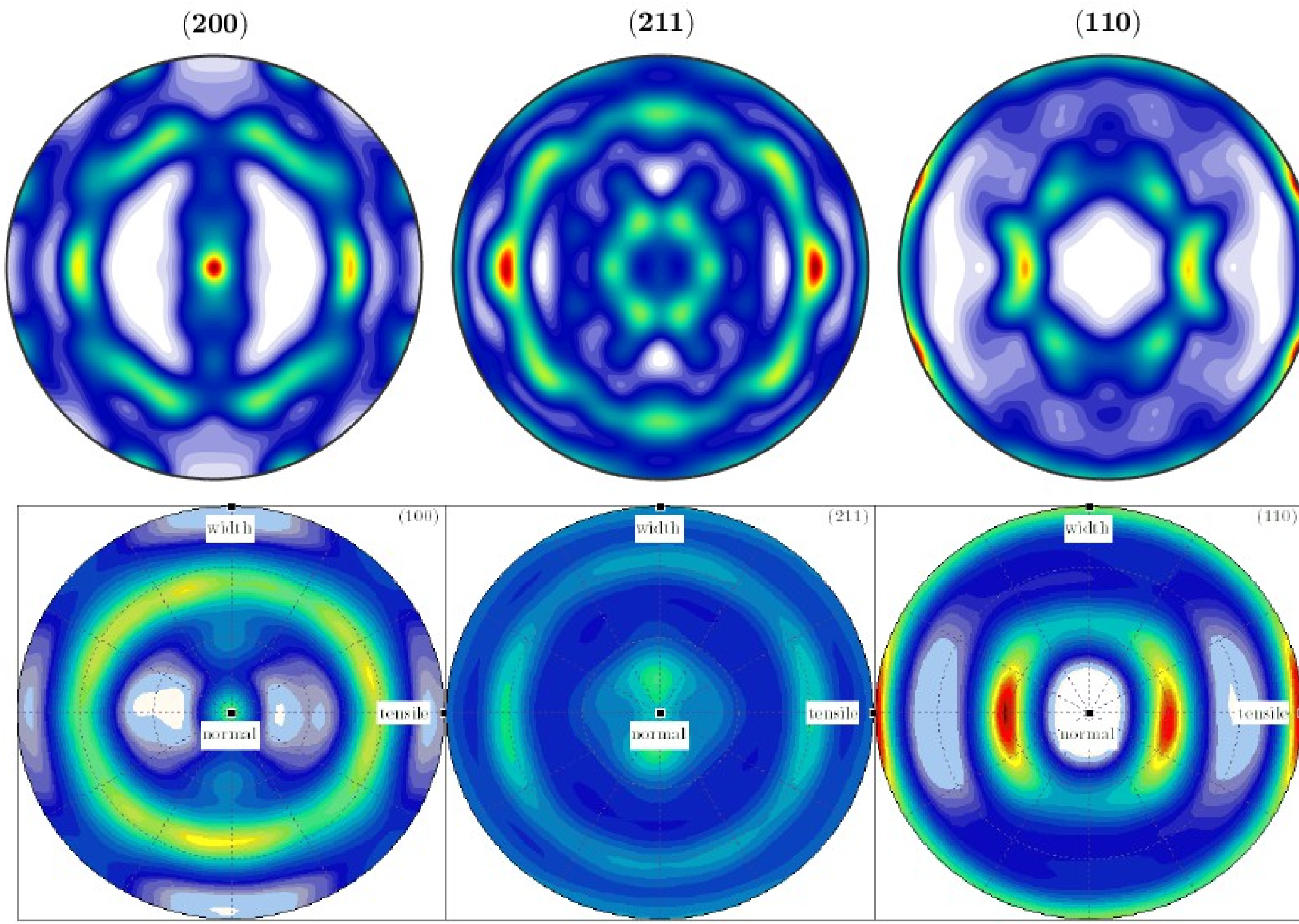
They are changed due to compressive deformation

Pole figure by neutron and X-ray （Undeformed IF steel）

RANS neutron

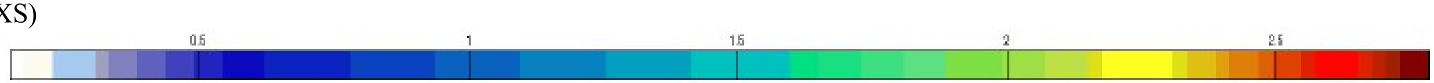
X-ray

Measured by Dr.Kumagai

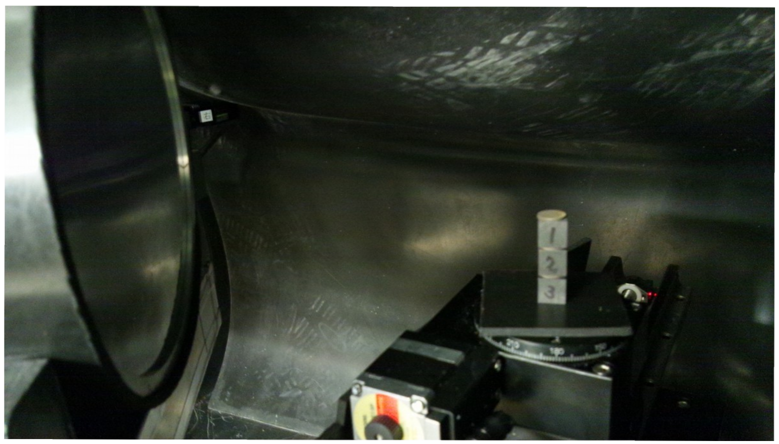


Discover with GADDS (Bruker AXS)

X-ray：Co-Kα

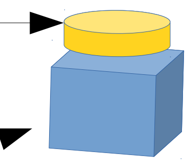


Quantitative measurement for austenite of dual-phase steel

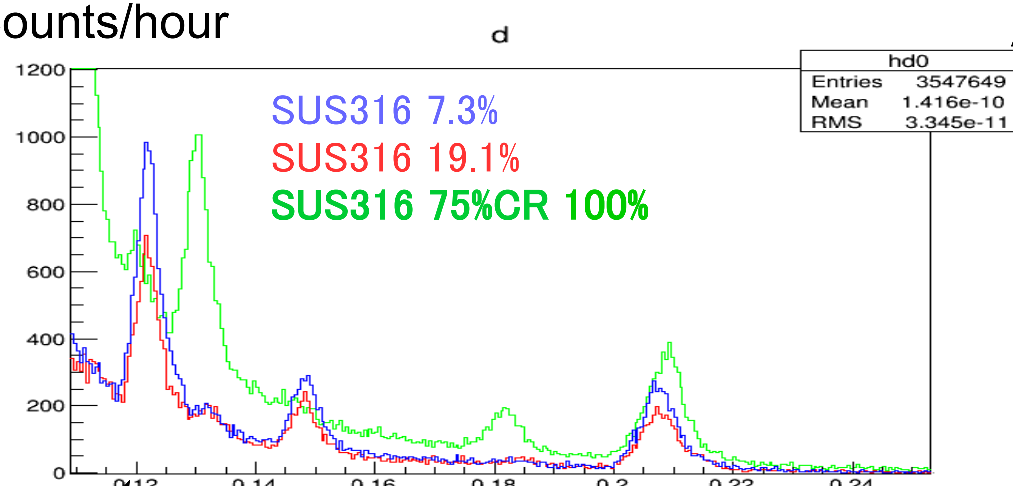


SUS316 25%CR（FCC, Austenite, φ10mm,w1mm）

Annealed SM440A（BCC, Ferite , $10mm^3$）



Counts/hour



[nm]

BCC 211　FCC 220　BCC 200　FCC 200　BCC 110　FCC 111

Peaks of both textures are measured

Austenite volume ratio

measured value (actual value)

6.7±0.8% (7.3%)

17.4±0.8% (19.1%)

~1% of accuracy

- Rietveld analized by Dr.Suzuki
  Z-Rietveld

R. Oishi et al, Rietveld analysis software for J-PARC Nucl. Instrum. Methods, A 600 (2009) 94–96

Summary

- Diffraction was measured with compact neutron source
  - Steel crystal texture was measured by 10 minutes.
  - Pole figure was made by 210 minutes.
  - Changes in texture due to compression deformation has been measured
  - Austenite volume ratio has been measured with an accuracy of 1%.

Compact neutron source is enable to measure diffraction and texture