Advances in Stretched Wire Tomography at Kyma

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About Kyma

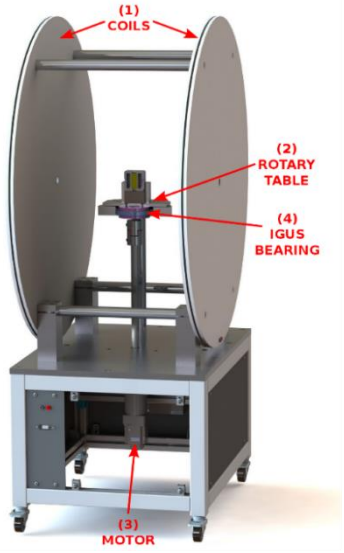
Elettra Sincrotrone Trieste

Kyma S.p.A.
(Elettra Sincotrone Trieste, Italy)

Kyma Tehnologija d.o.o.
(Sežana, Slovenia)

Core products

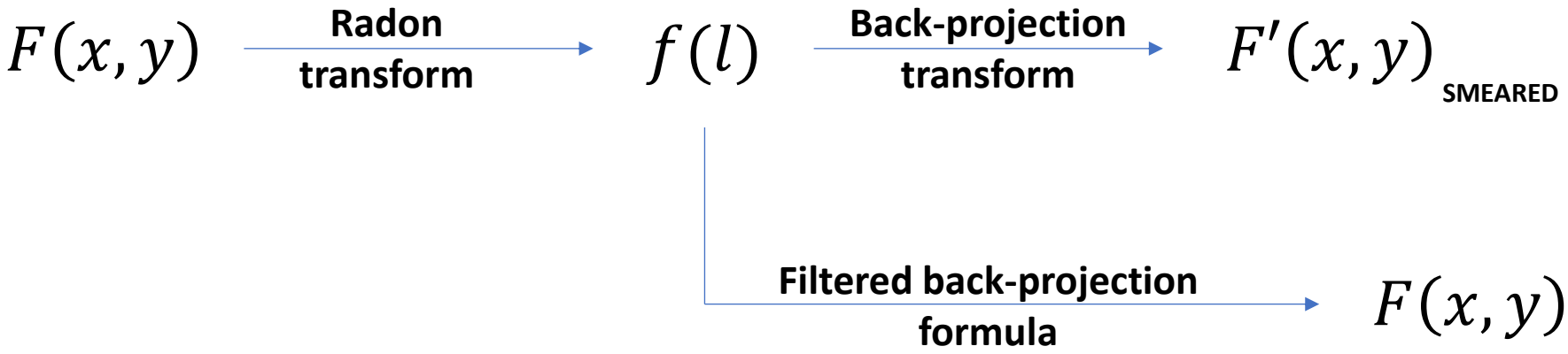
- Design, assemble, tune various IDs
  - LPU, EPU, IVU
  - Wigglers, Phase shifters
- Measurement benches
    - Helmholtz Coil System
    - Flip coil and Hall probe bench
    - Software solutions
    - Tomography



Tomography

- Imaging by sections
- “Looking” at something from different directions can give information about the “internals” of it
- Medicine: Computed Tomography
  - X-ray scans in different directions can yield a 3D image
- Mathematical description:
  - Radon and inverse Radon transform
  - $f(l) \rightarrow f(x, y)$: Filtered back-projection transform
    - FT → filtering → IFT → Back-projection transform

Tomography



- Filtered back-projection formula

$$F(x,y) = \frac{1}{2}\mathcal{B}\{\mathcal{F}^{-1}[|S|\mathcal{F}(\mathcal{R}f)]\}$$

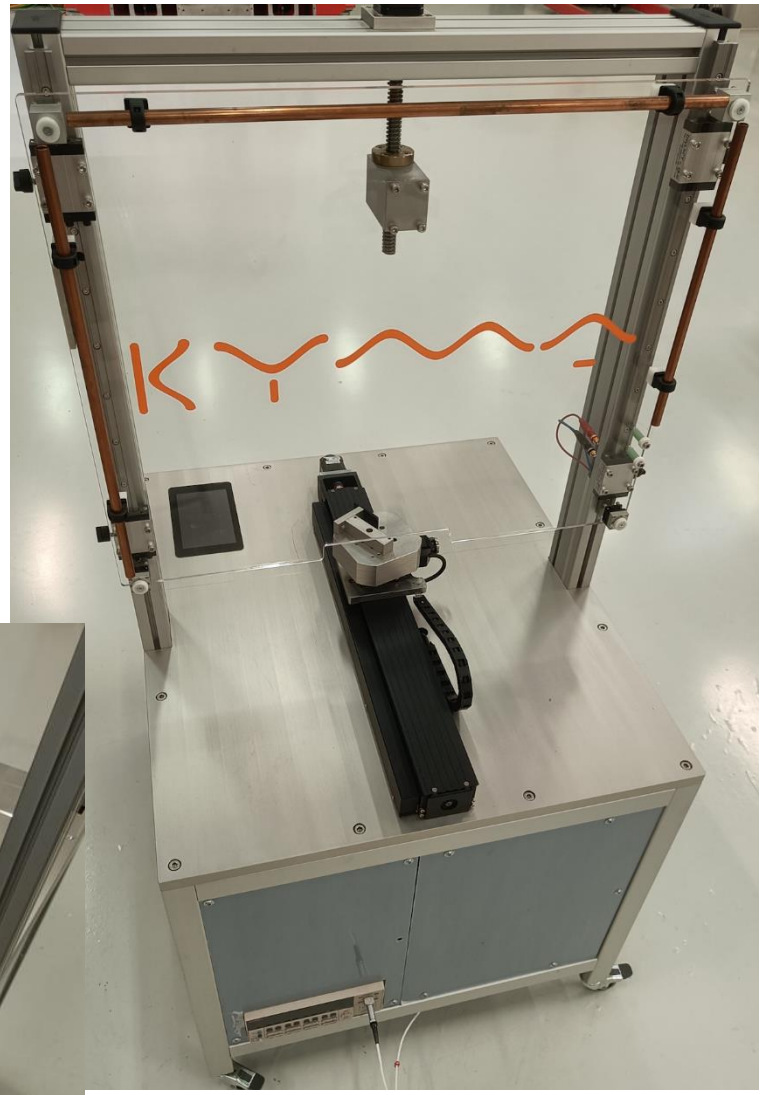
$\mathcal{R},\ \mathcal{F},\ \mathcal{B}$ – Radon, Fourier, Back-projection transform

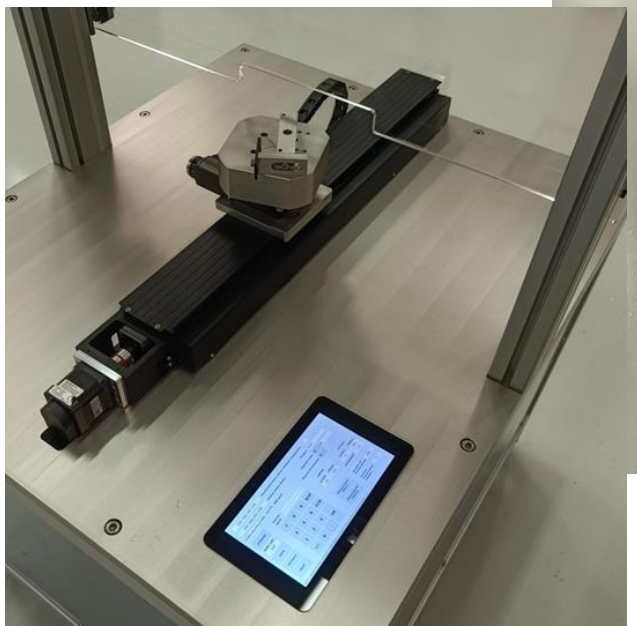
$|S|$ – filter transform

$$f = f(S,\theta)$$

Stretched Wire Tomography @ Kyma

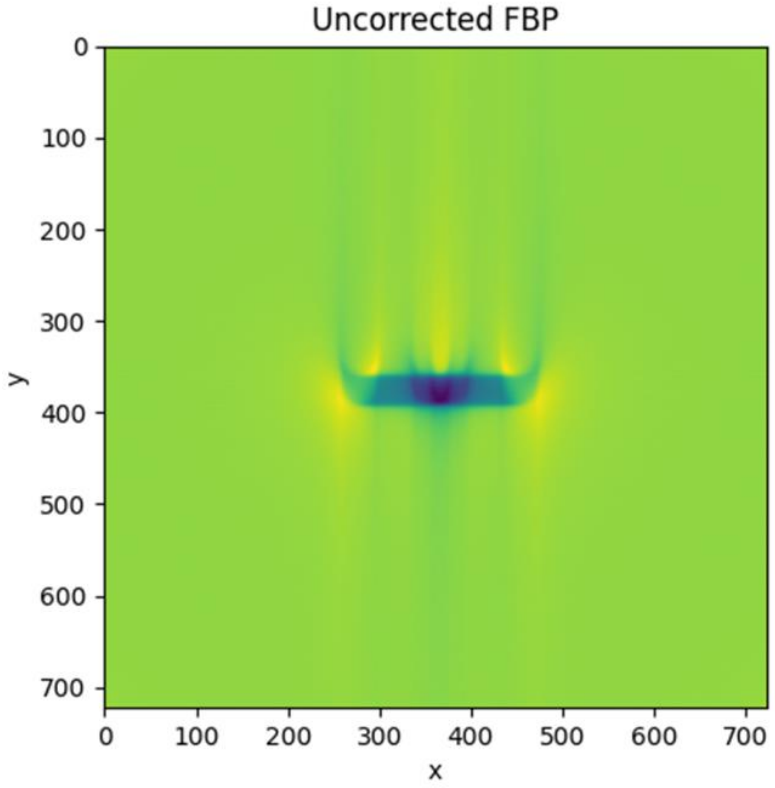
- Linear and rotary stage
  - Stepper motors and controllers
  - Induced voltage measurement during linear motion
  - Rotary steps between measurements
- Keithley 2182A
- Single Cu wire loop (100 µm)
- Raspberry Pi
- Manual wire height adjustments
- Compact and cost-efficient system

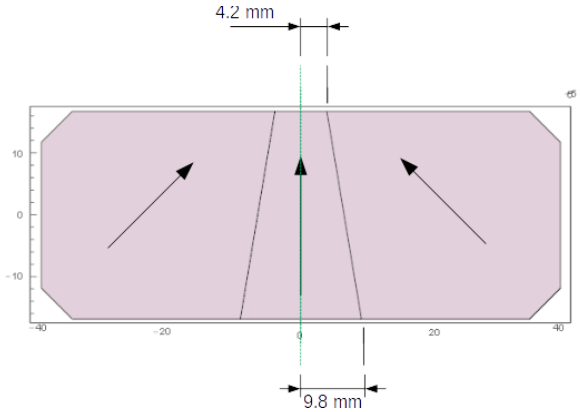


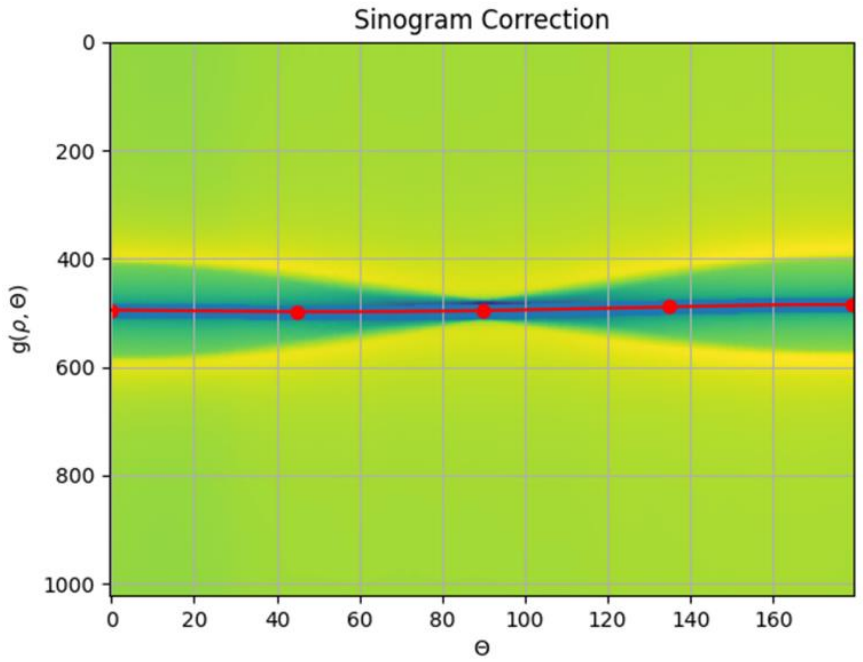


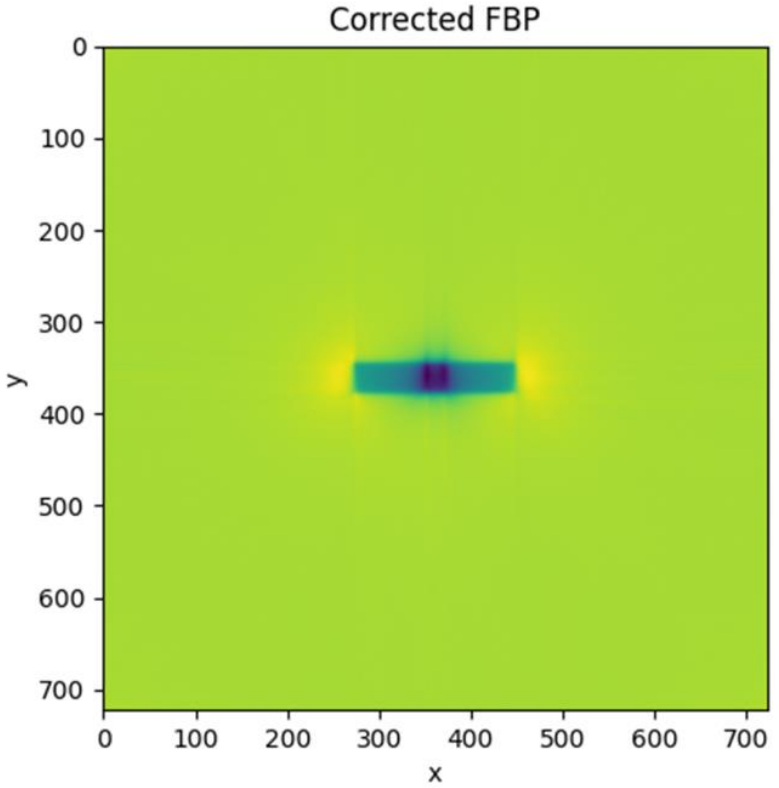
Past results

- “manual” sinogram correction

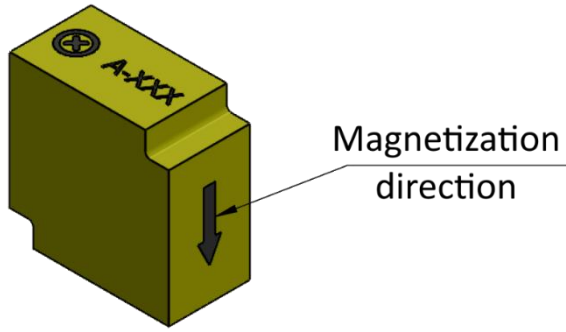




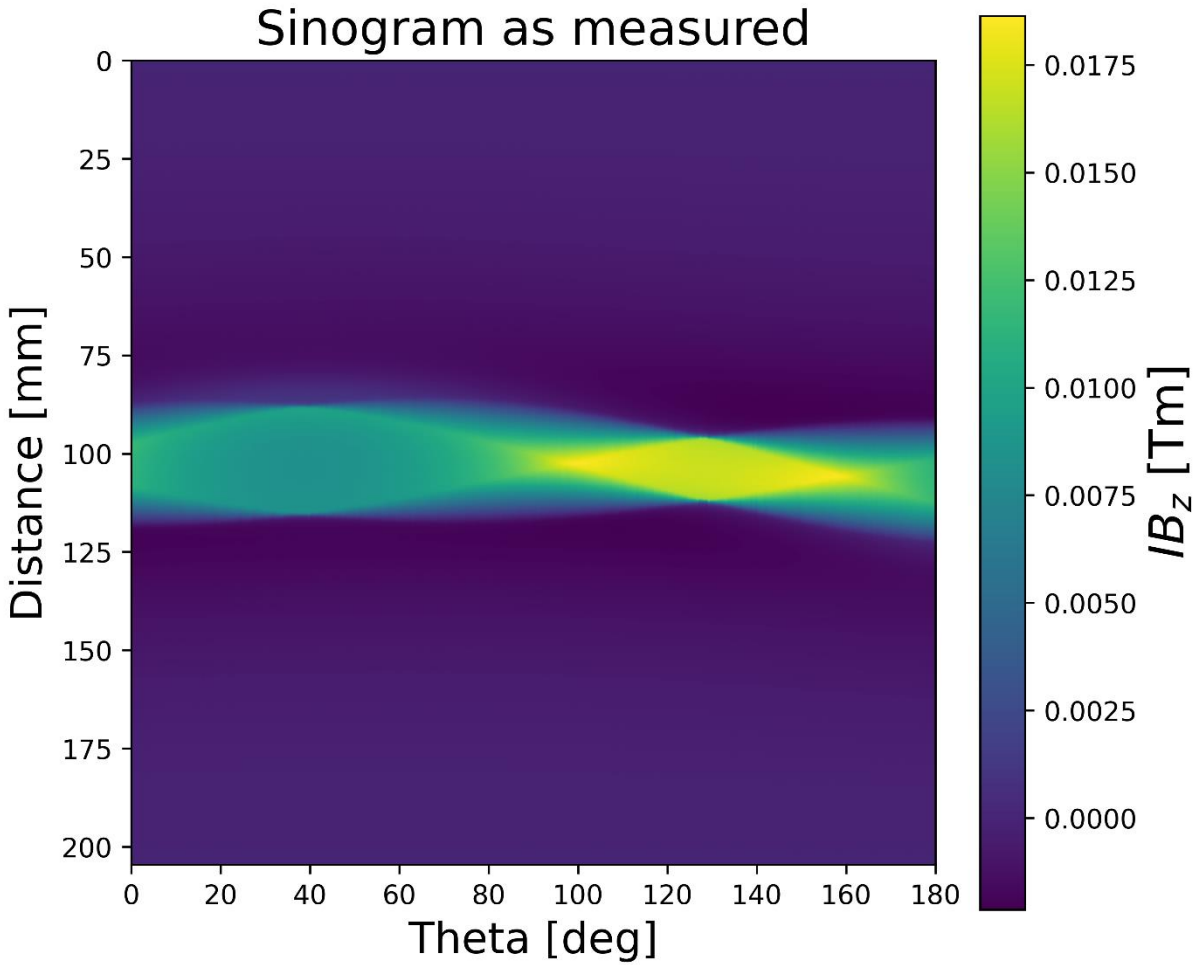


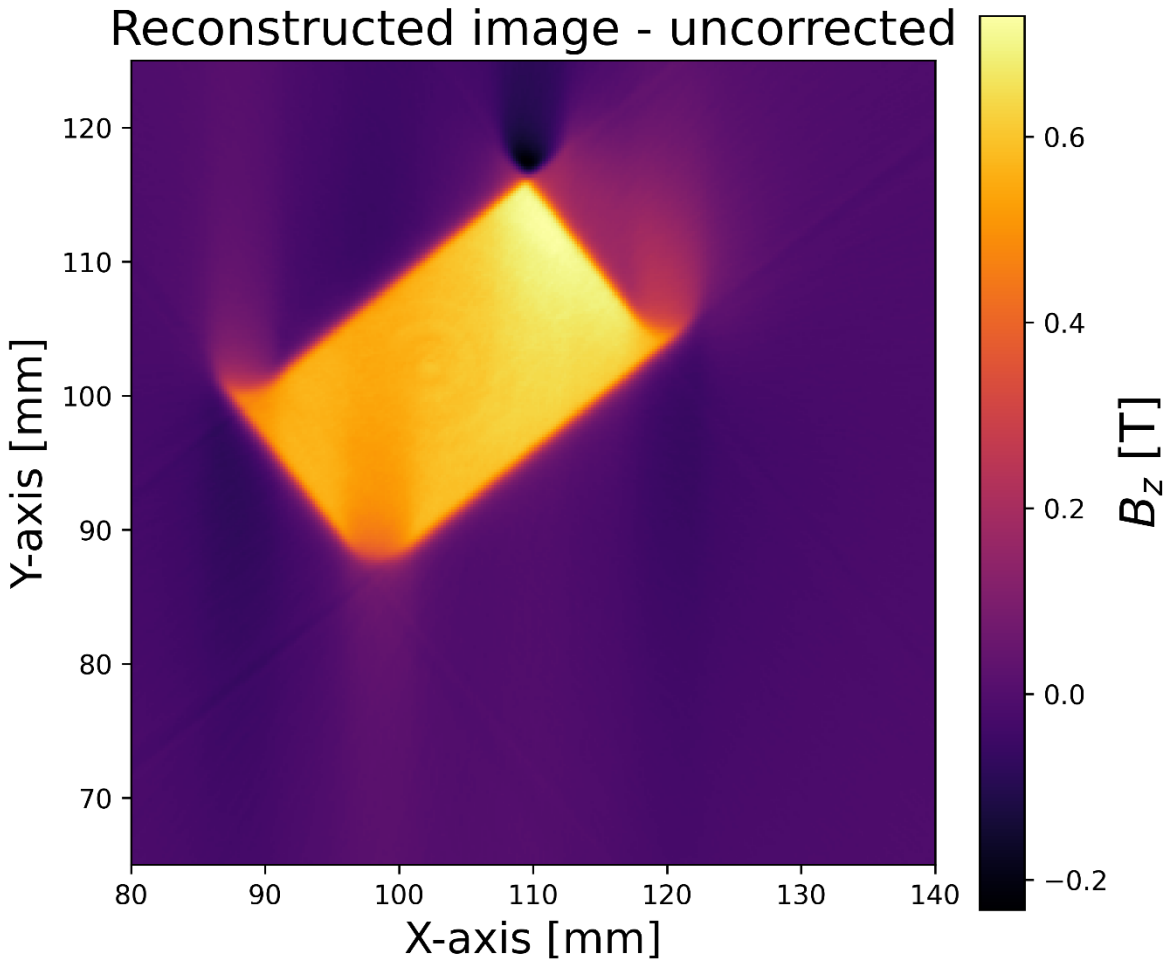


Streched Wire Tomography @ Kyma



Uncorrected

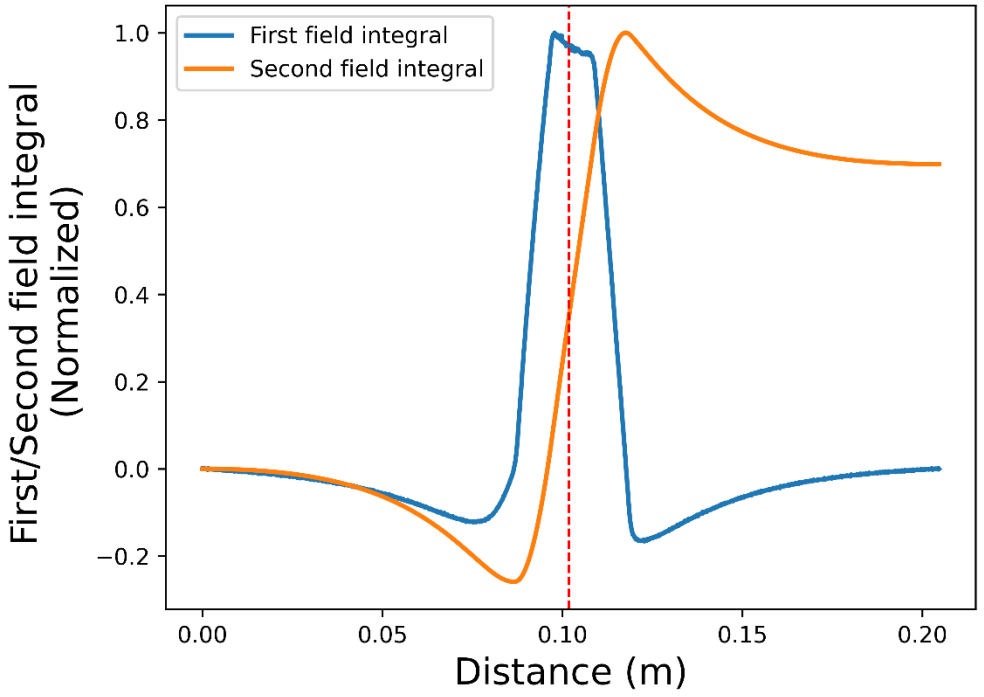


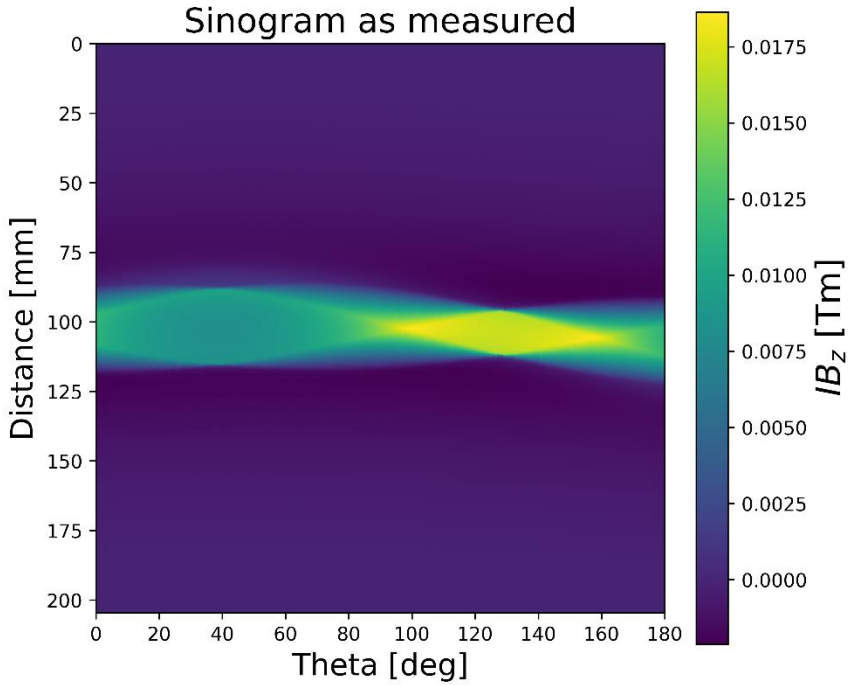


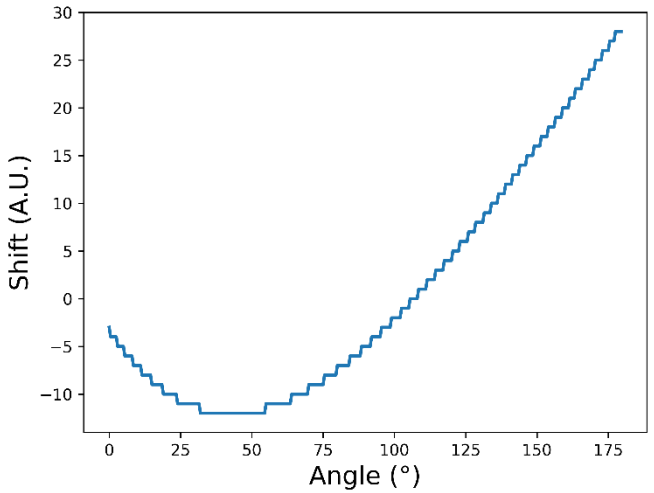
Streched Wire Tomography @ Kyma

“Magnetic center” detection algorithm

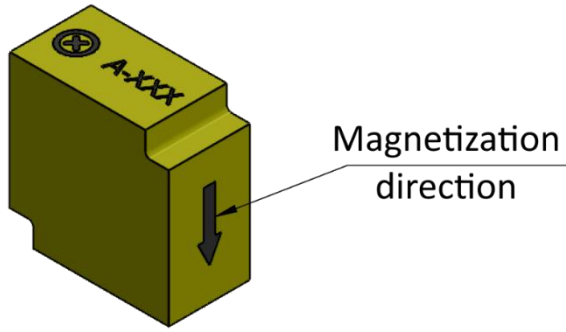
- Calculate the second field integral
- Find and relocate the half value of second field integral
- Shift each projection of the sinogram accordingly



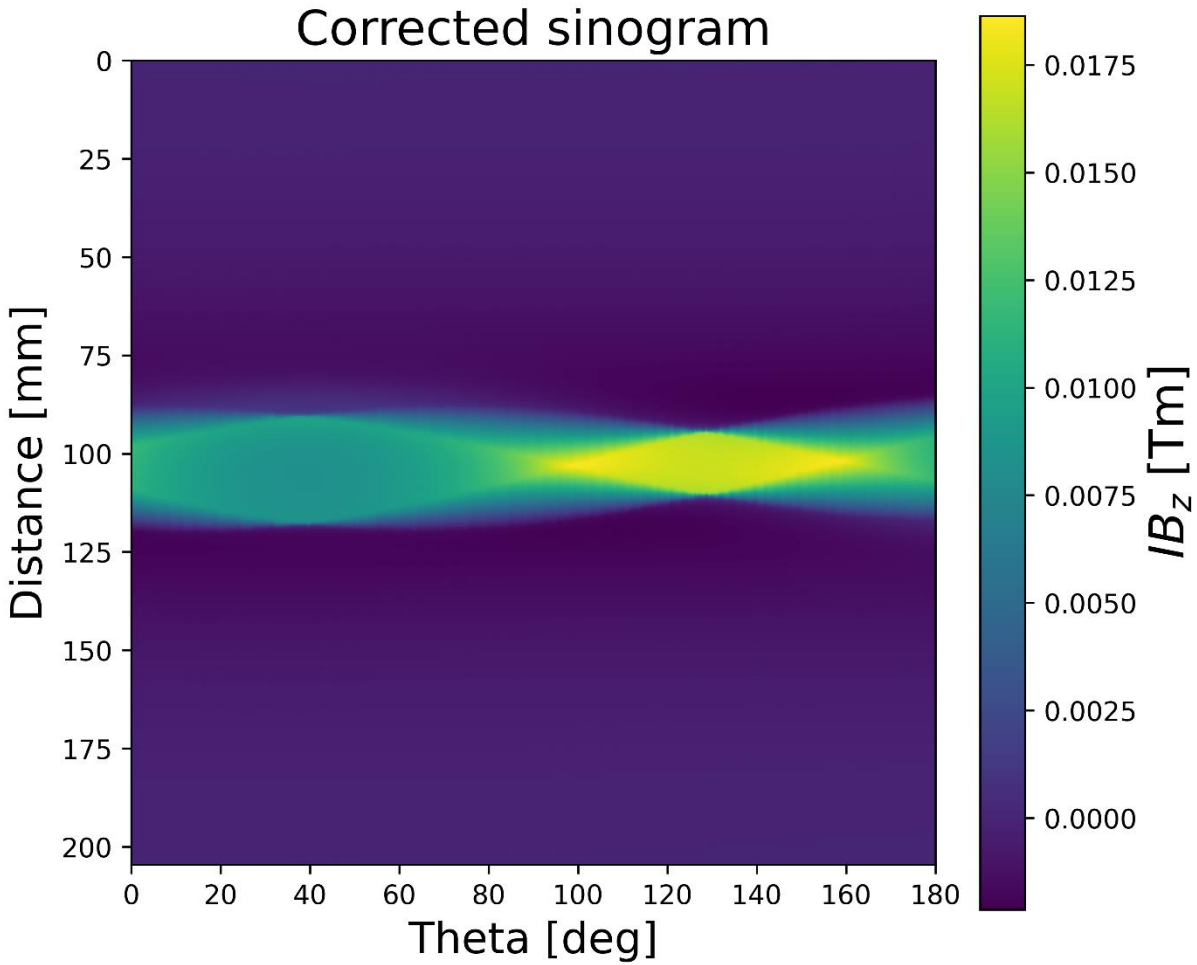


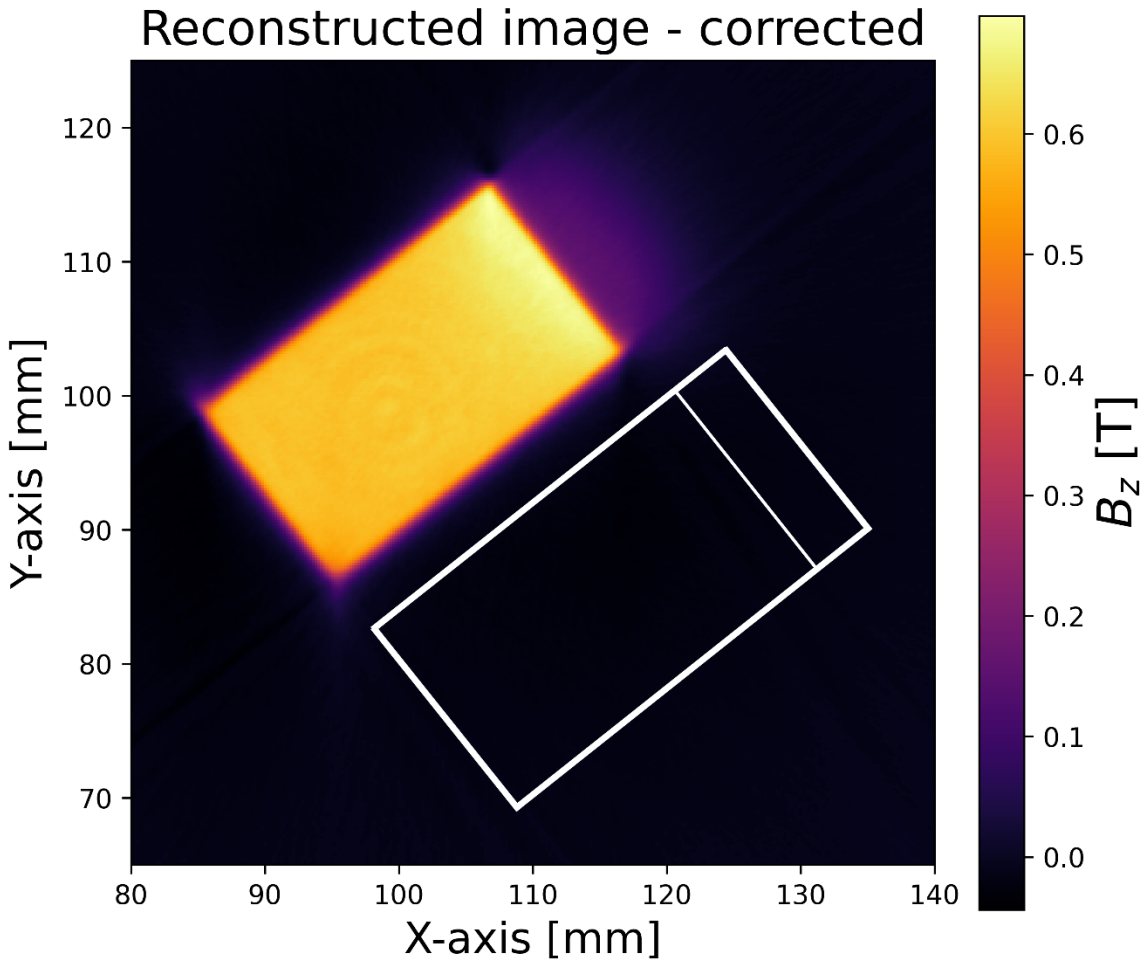


Streched Wire Tomography @ Kyma



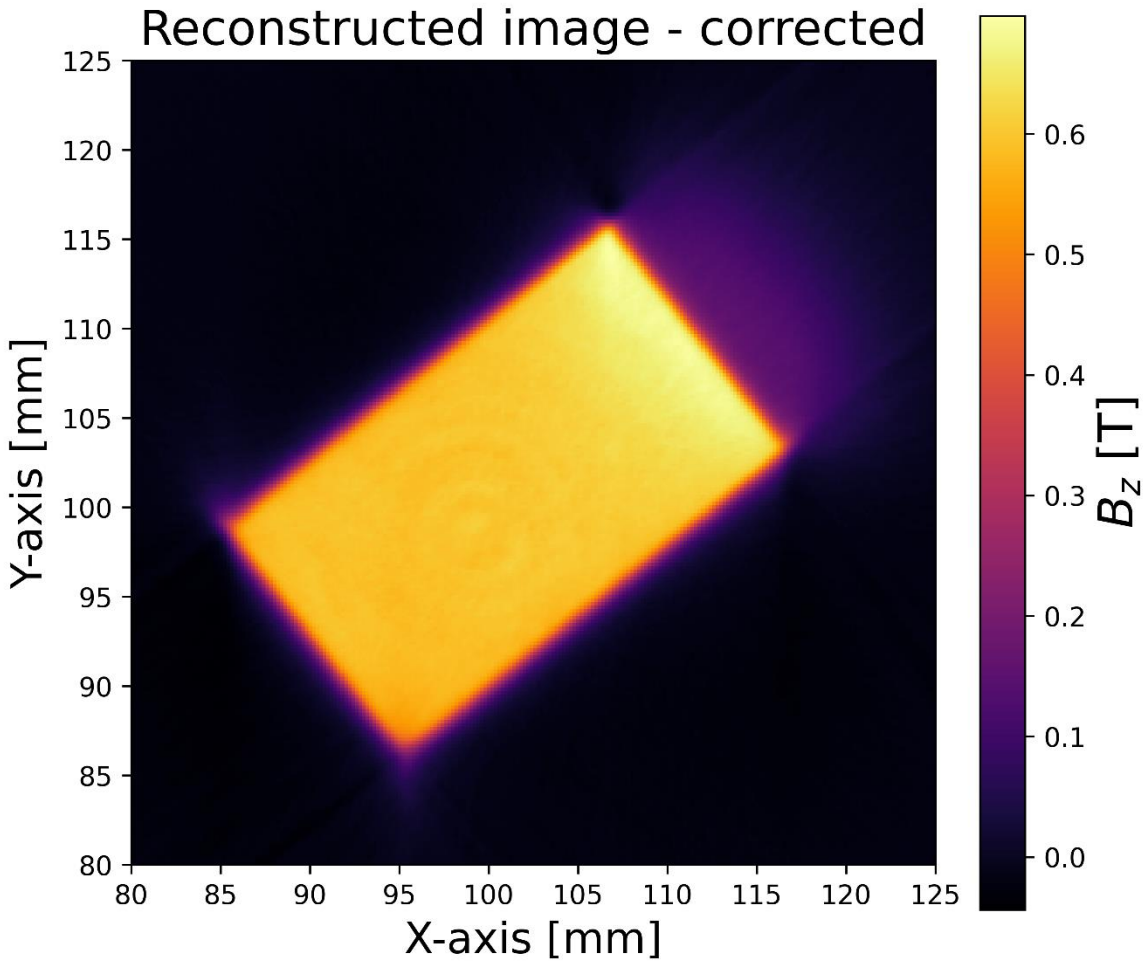
“Magnetic center” correction

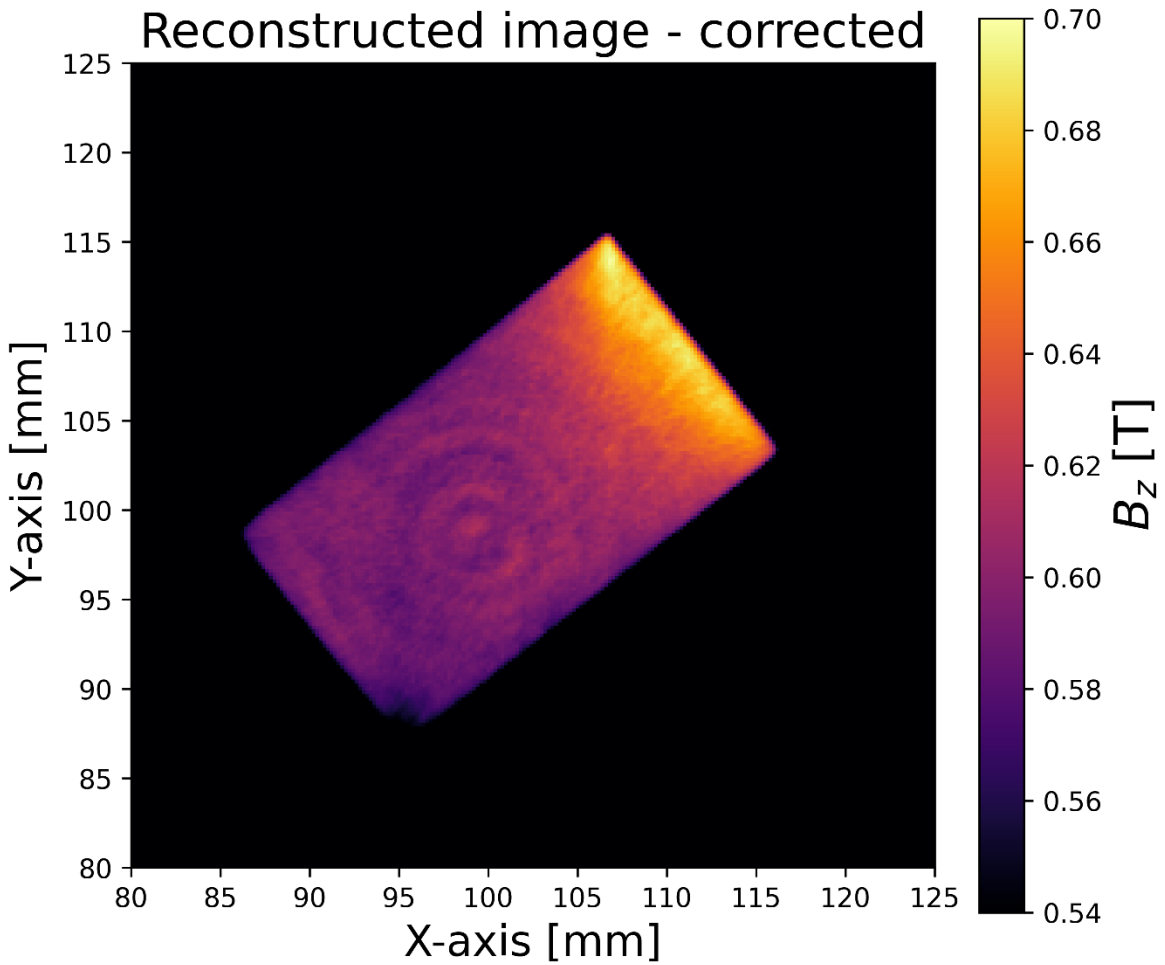




Streched Wire Tomography @ Kyma

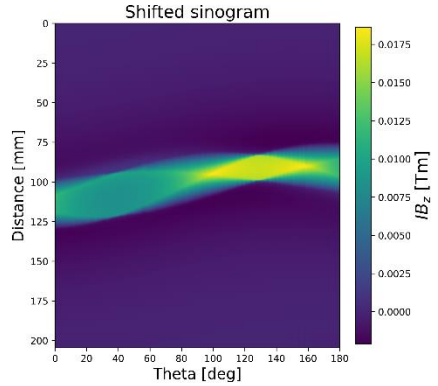
- Appearance of ripple-like image artefacts

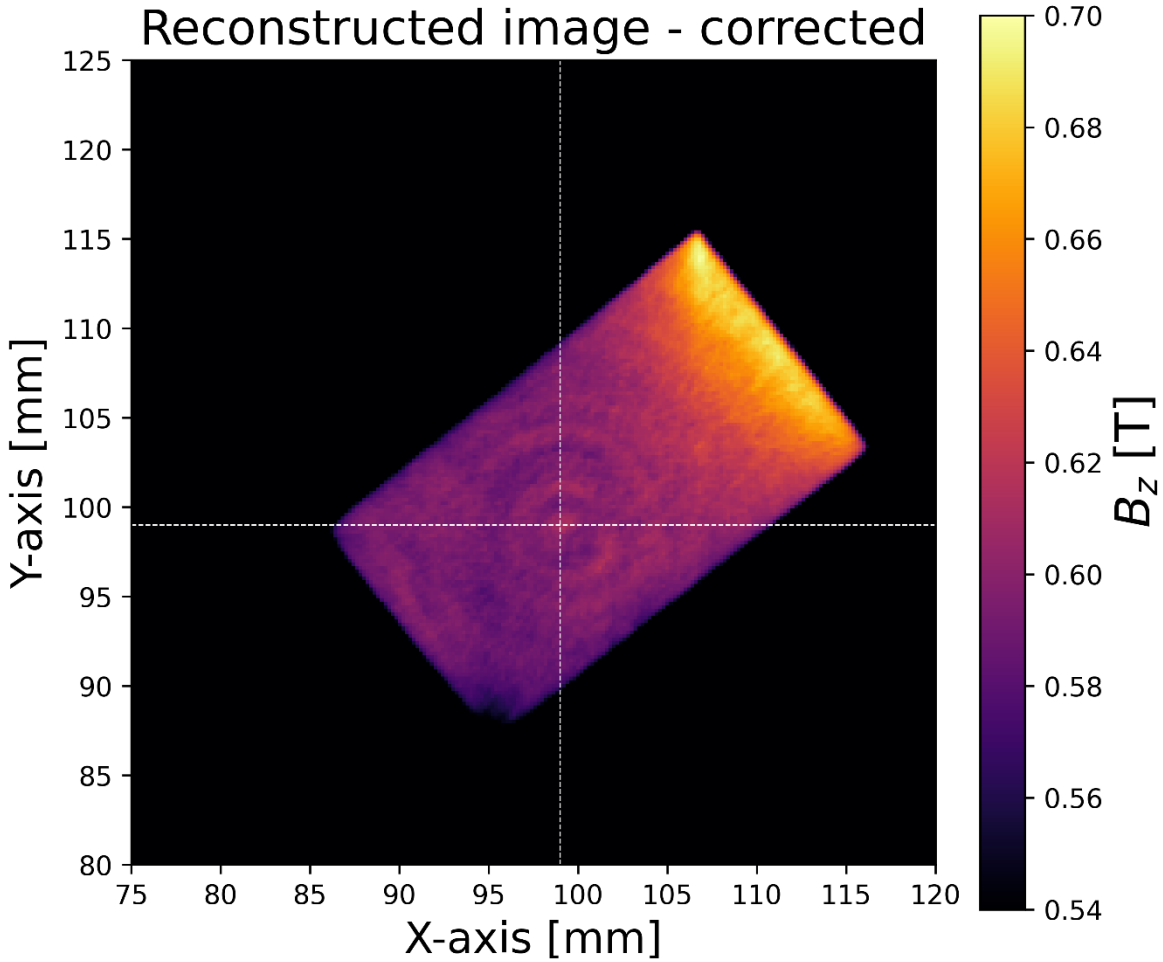


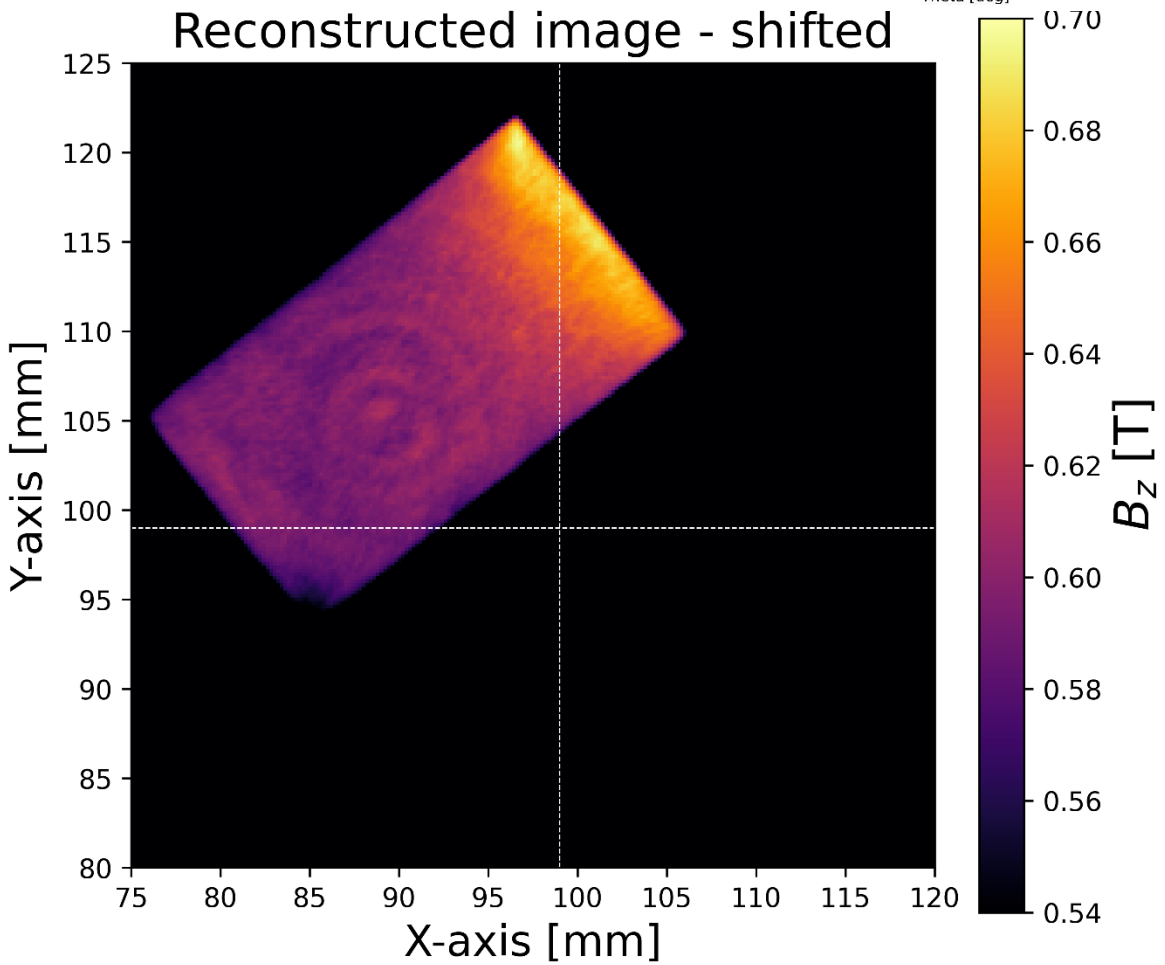


Streched Wire Tomography @ Kyma

- Modifying sinogram before inverse Radon transformation



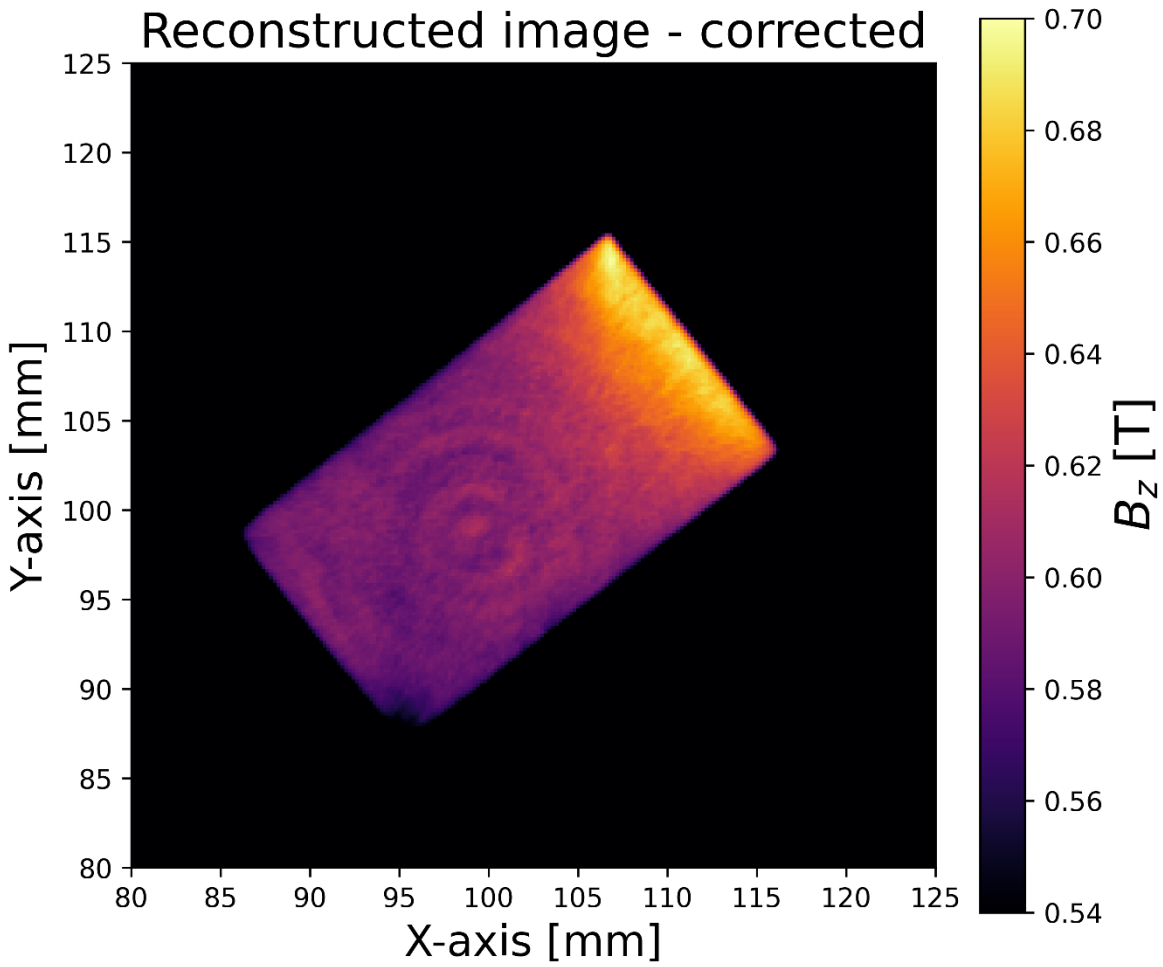




Ripple pattern investigation

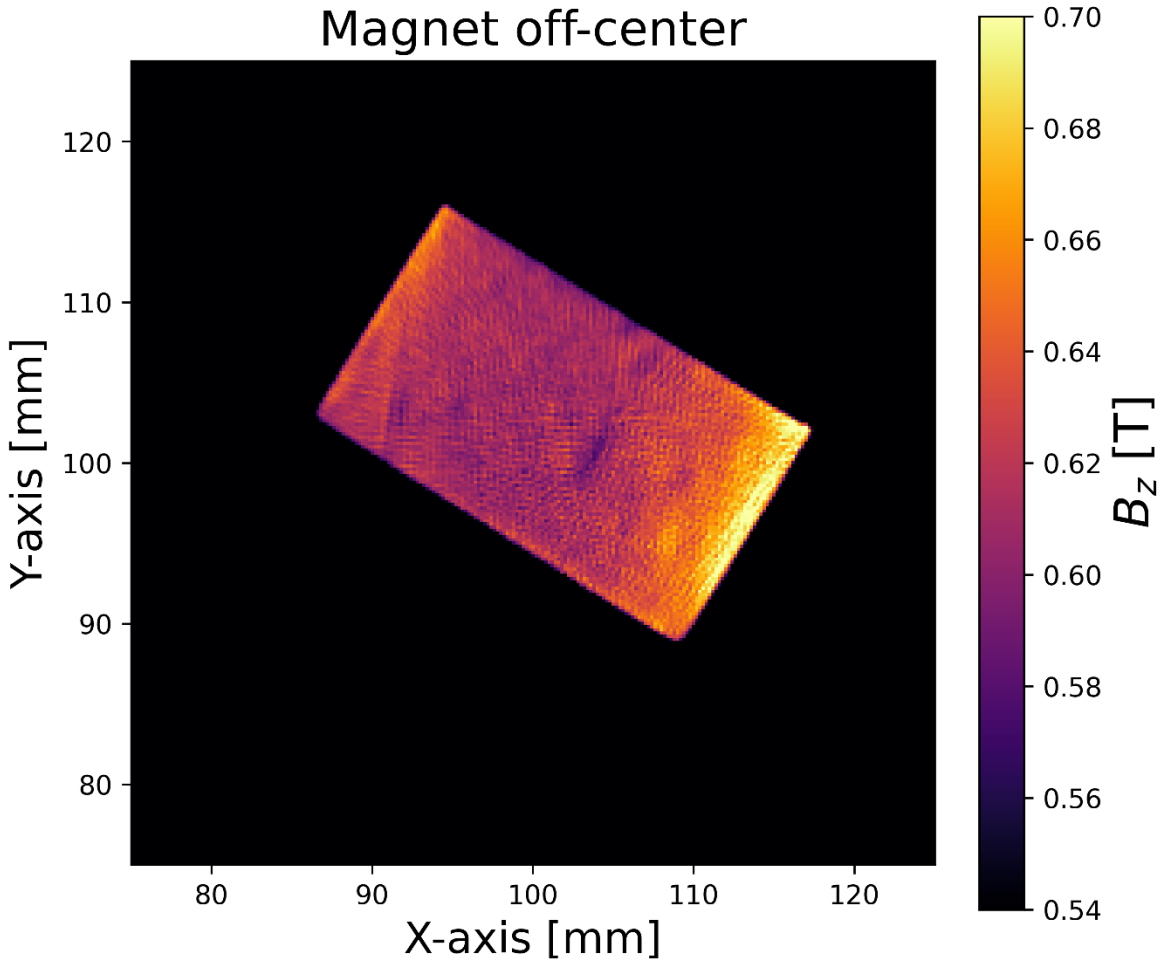
Magnet 1

- In the center of rotation



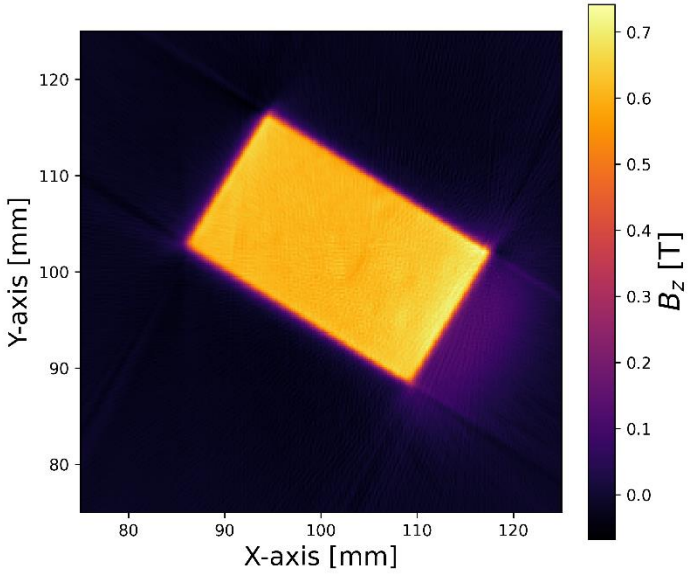
Magnet 2

- Off-center of rotation

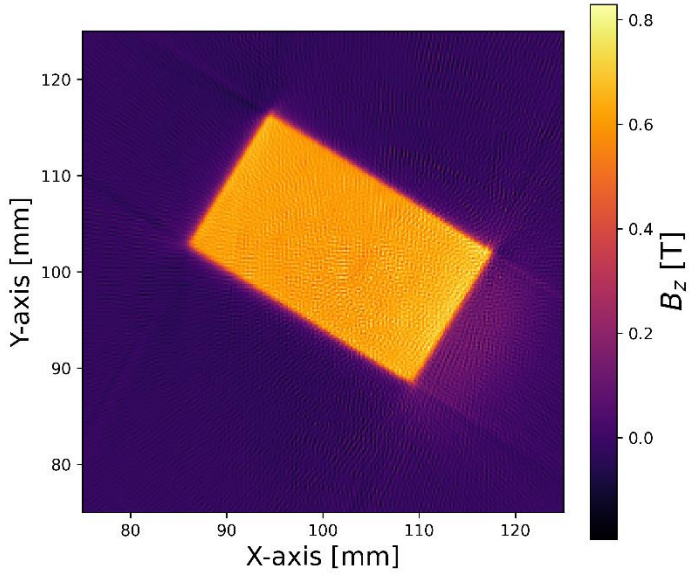


SWT – Filter comparison (complete z-scale)

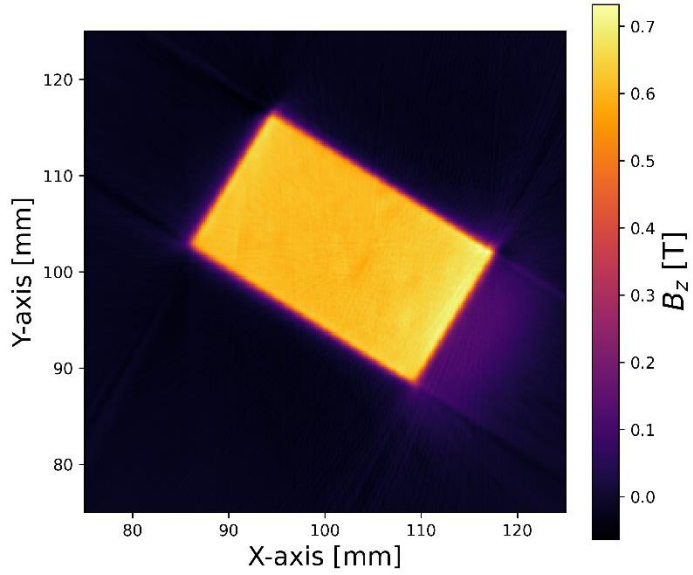
Hamming



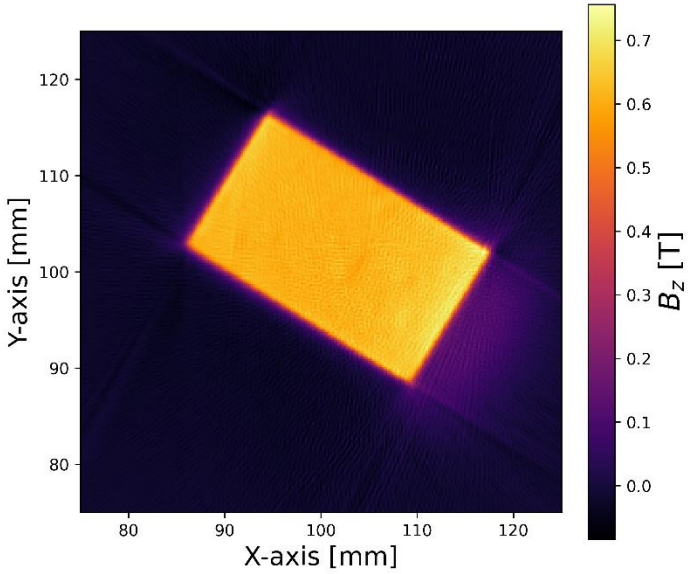
Shepp-logan



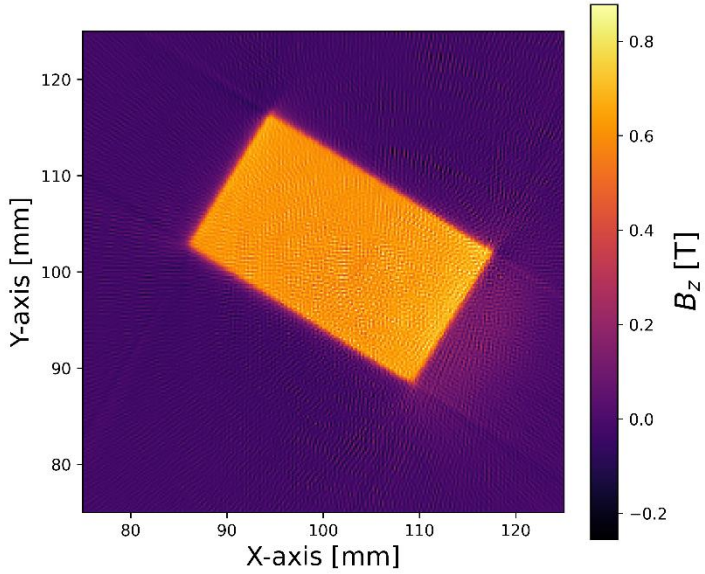
Hann



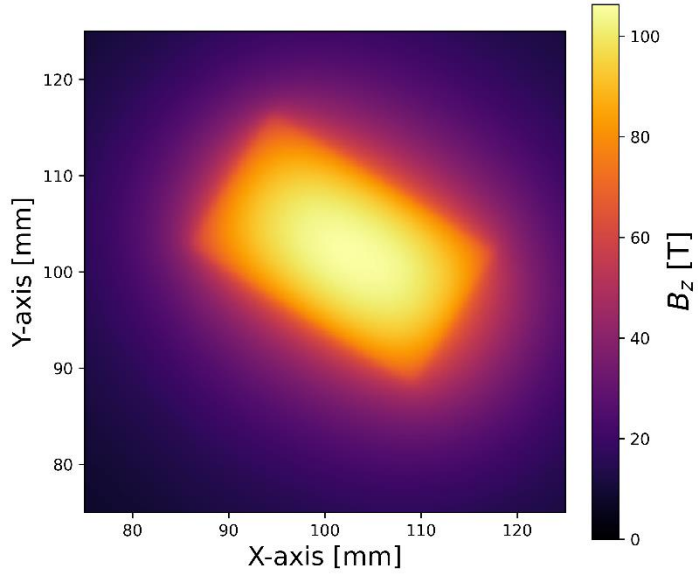
Cosine



Ramp

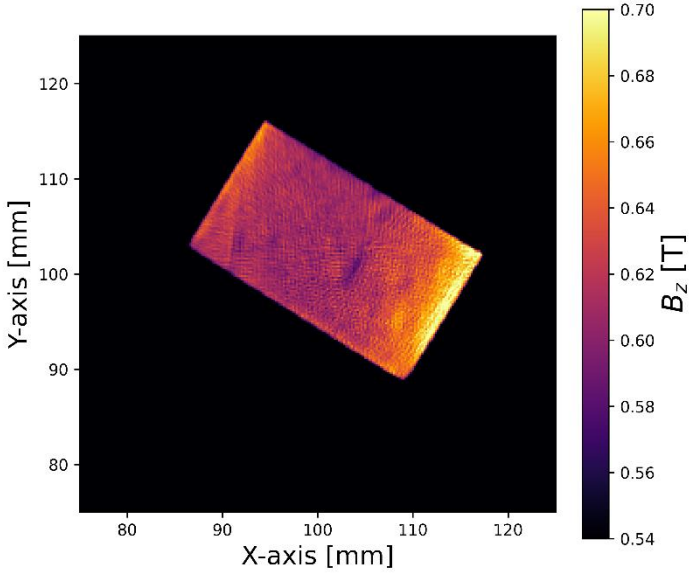


None

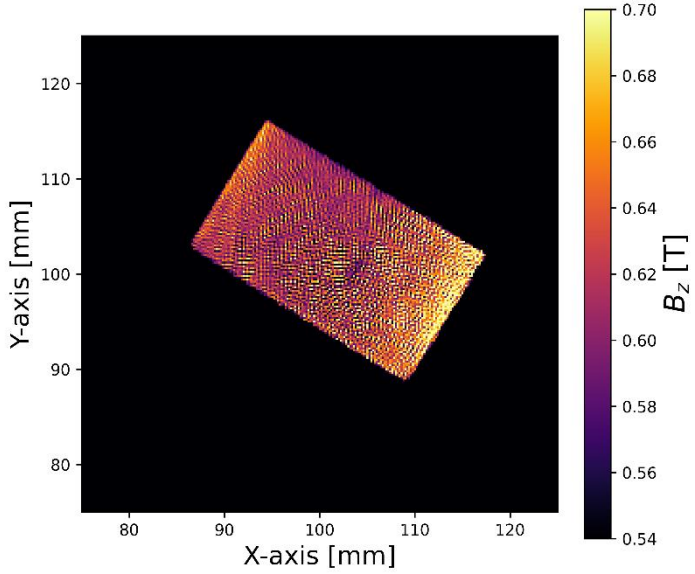


SWT – Filter comparison (limited z-scale)

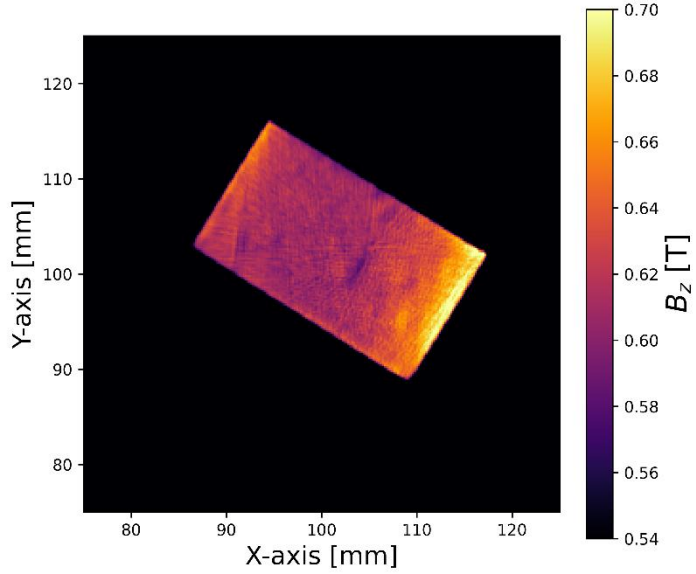
Hamming



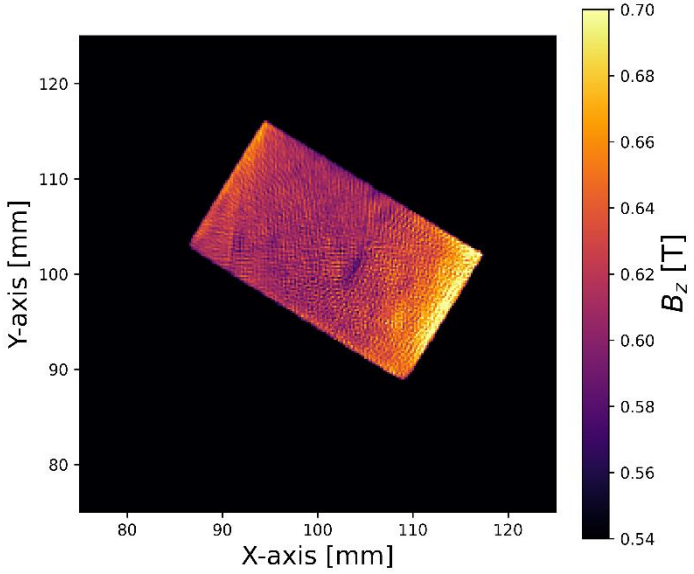
Shepp-logan



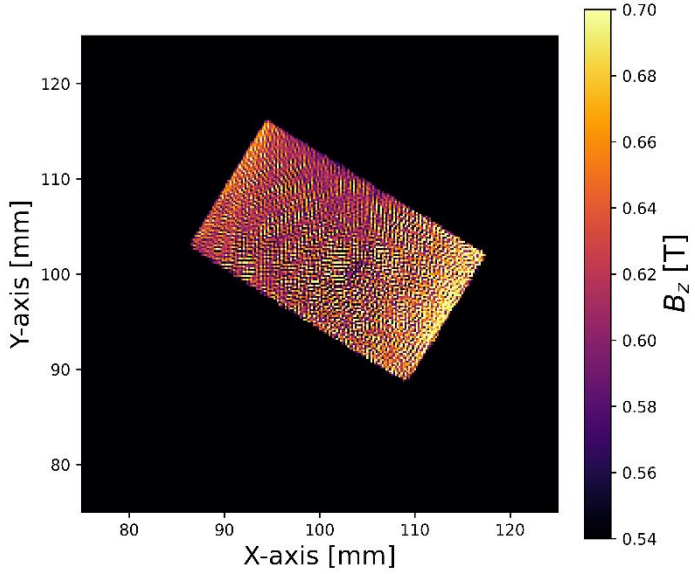
Hann

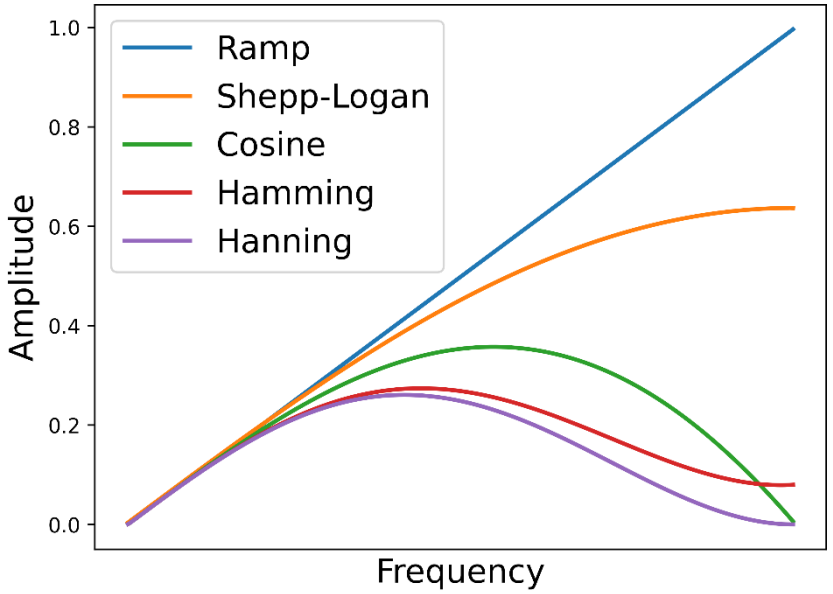


Cosine

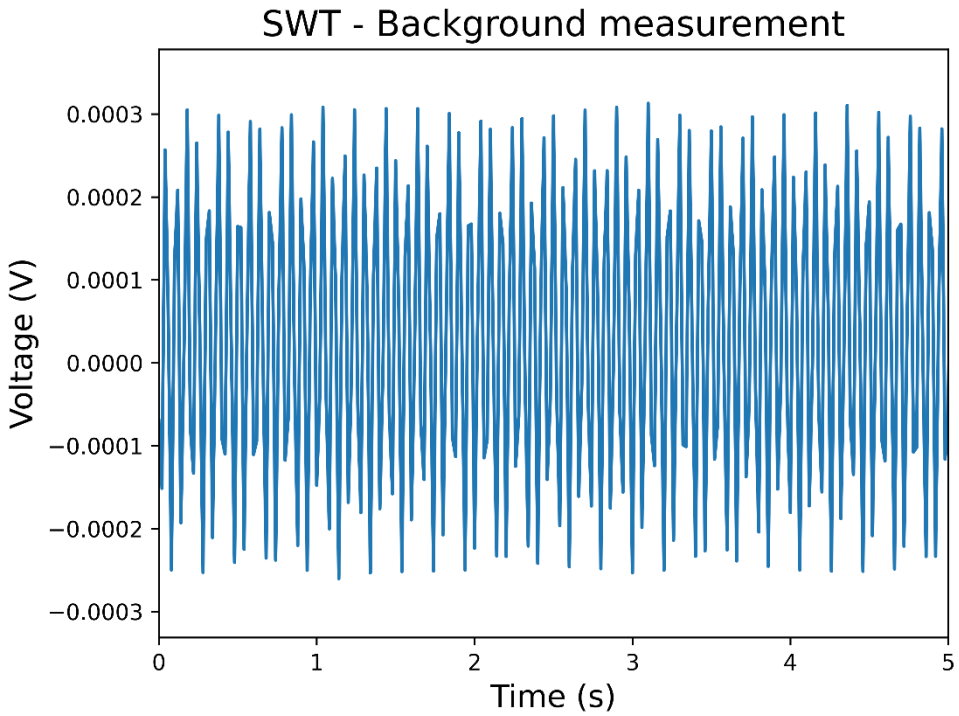


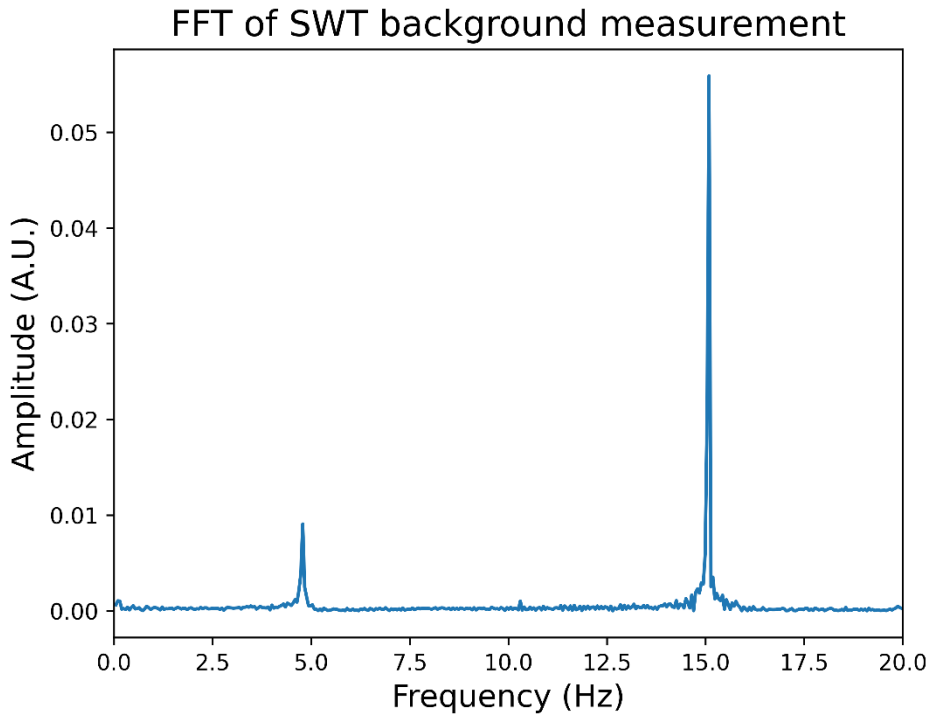
Ramp



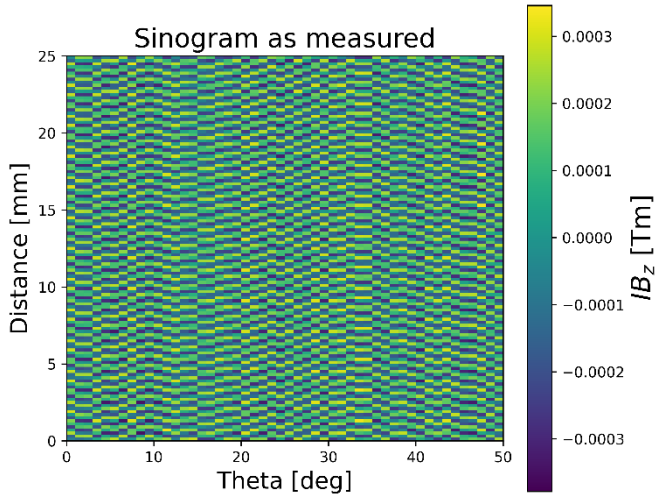


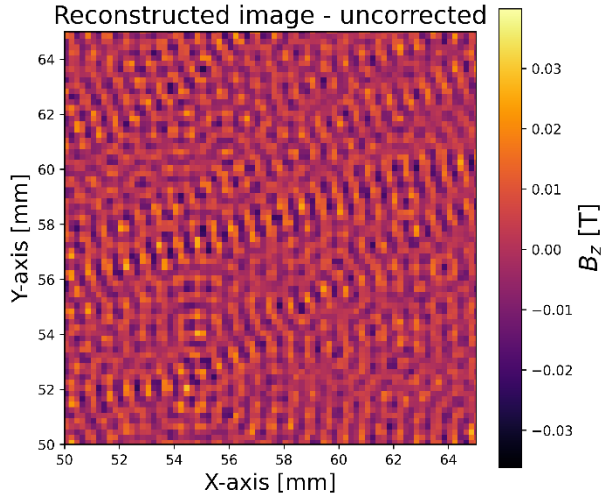
SWT – Background assessment





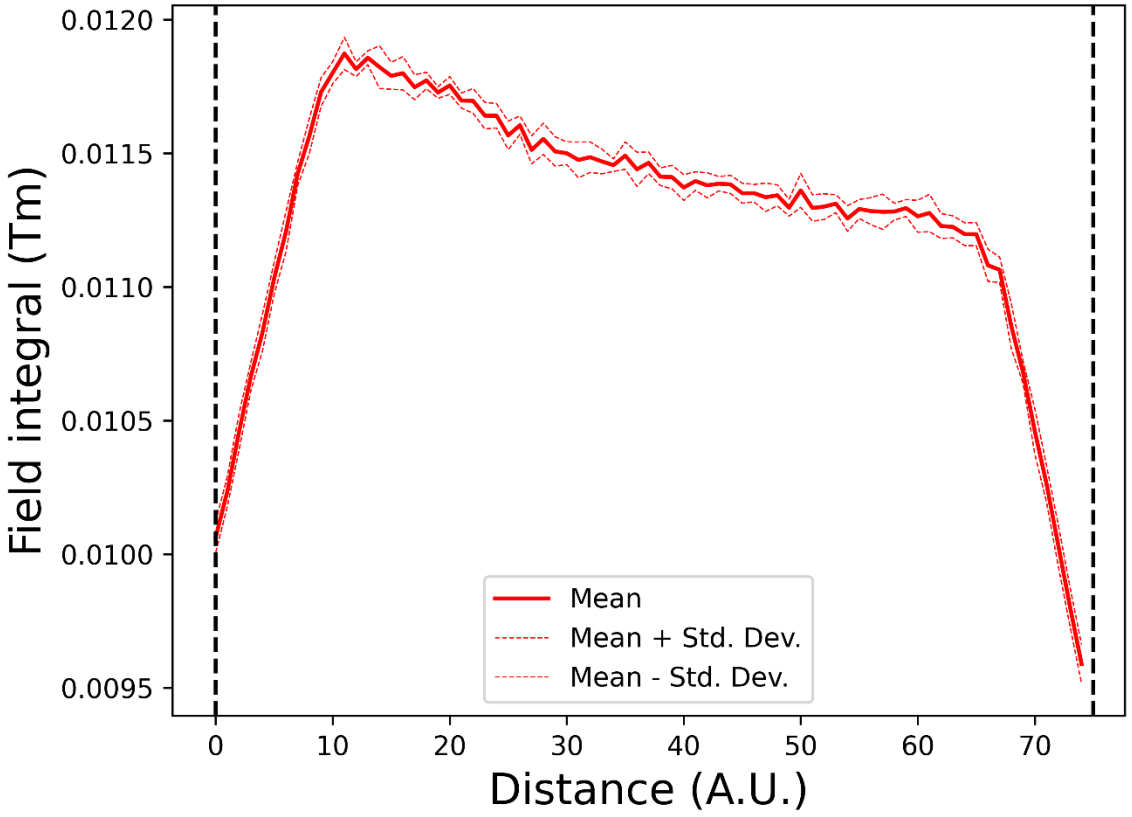
- Issue: presence of specific frequencies in the background signal

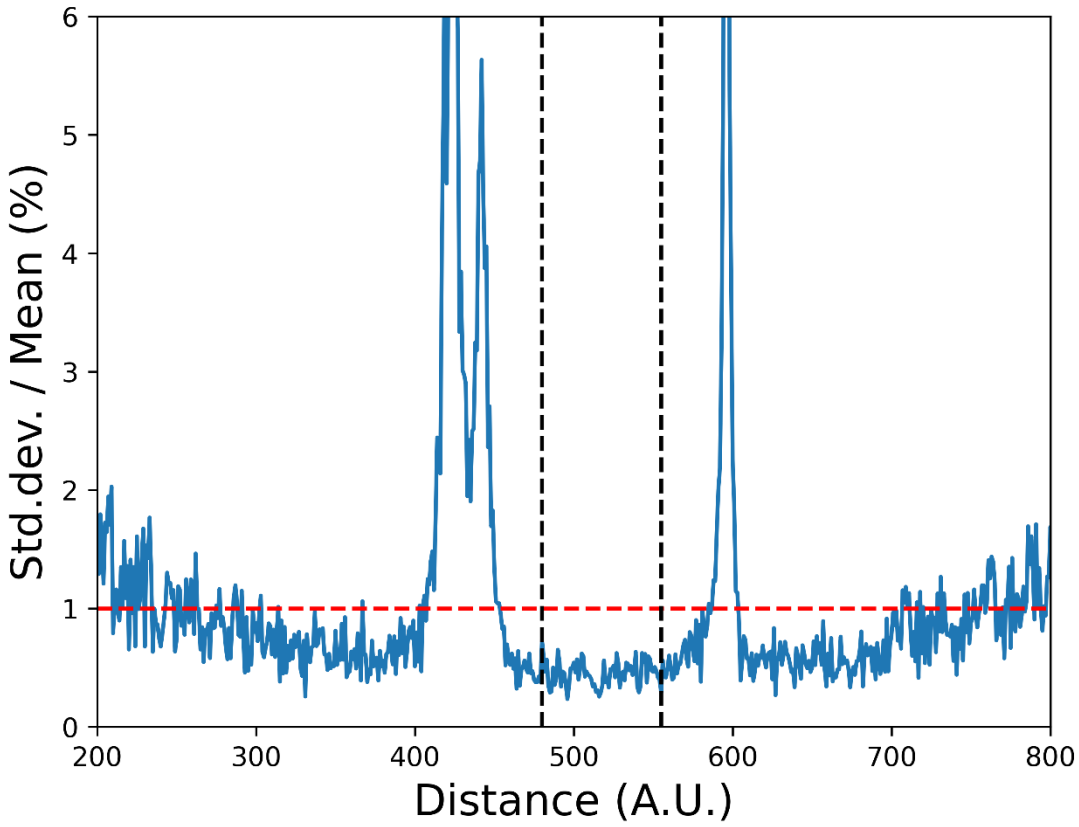




SWT – Measurement “repeatability”

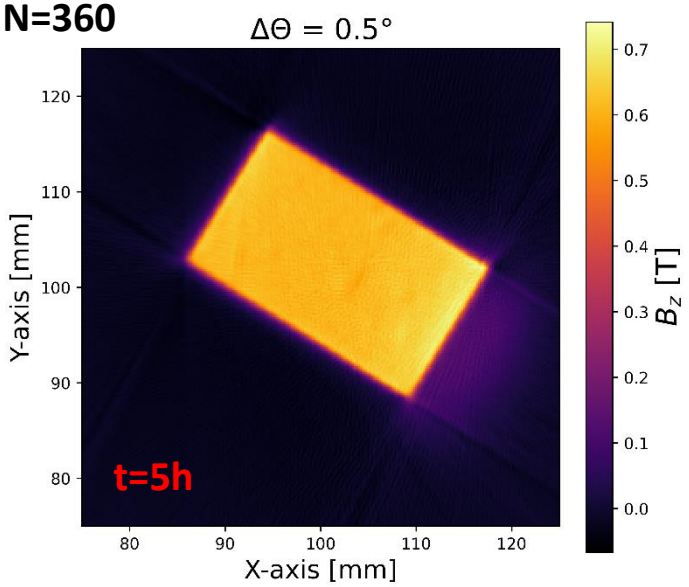
- Repeating measurement (10x) of one of the magnets, just above its surface



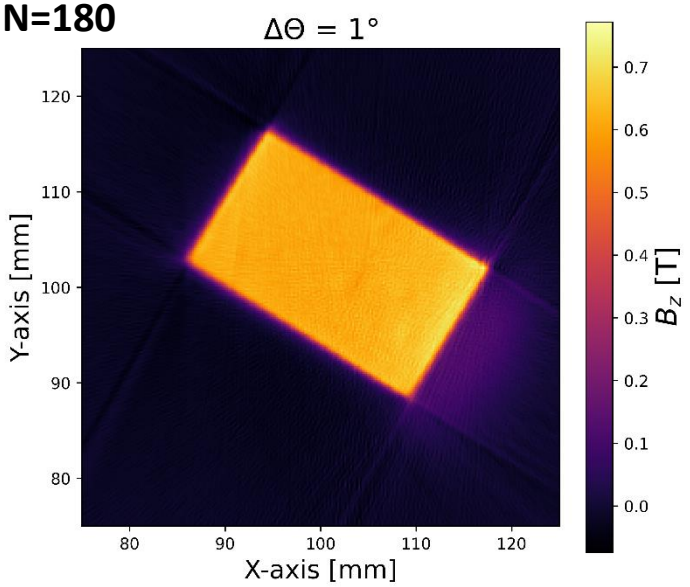


SWT – Reducing number of measurements by angle

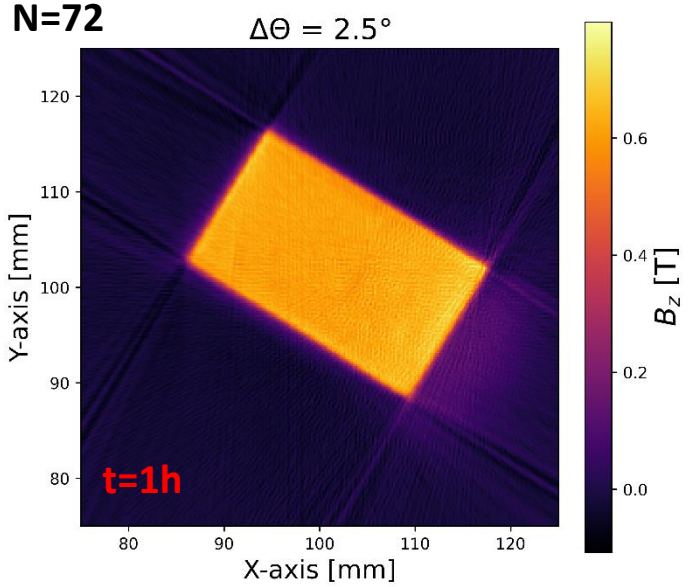
N=360



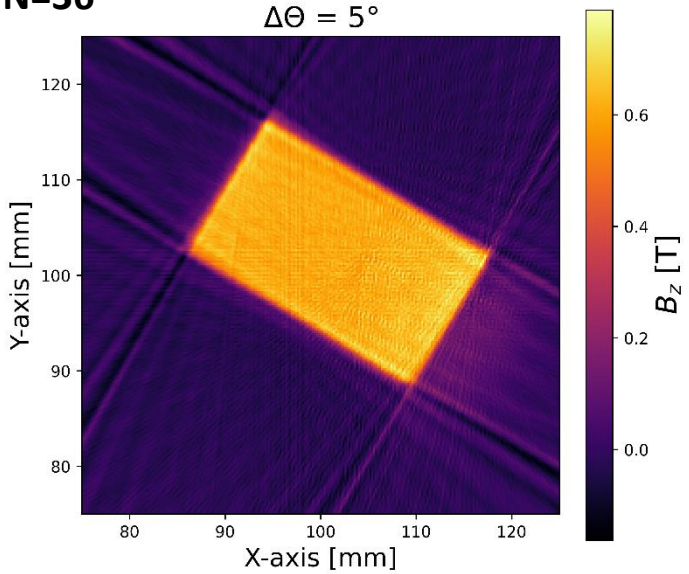
N=180



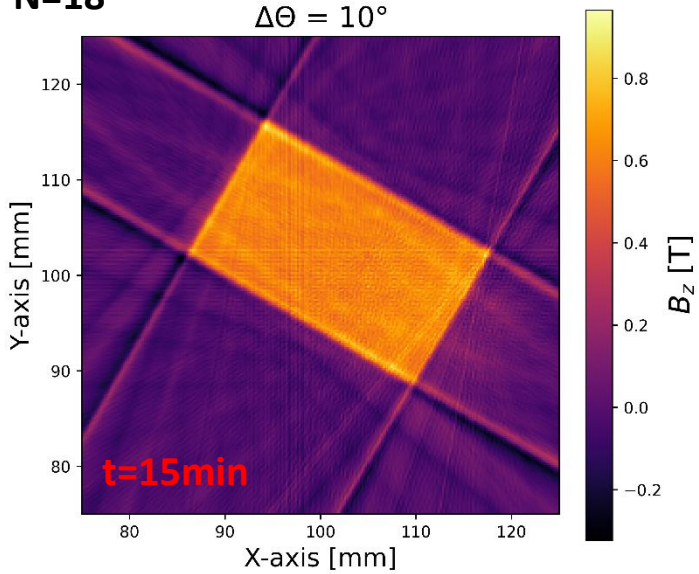
N=72



N=36



N=18



Recap of stretched wire tomography system

- Alternative method to visualize in-plane properties of magnetic flux density component
  - Measurements close to magnet surface
  - 0.2mm spatial resolution
  - Repeatability below < 1%
- Potential uses:
  - 2D magnetic flux density images of aged or degraded magnets (mechanical or irradiation damage)
  - Learning tool (tomography in general, direct imaging magnet's properties)
- Current limitation: time-consuming measurement
- Future improvement:
  - System synchronization, motor tuning
  - Simultaneous multi-channel measurements

Acknowledgments:

- Mirko Kokole
- Žan Mahnič
- Andrej Nabergoj
- Jure Počkar