Improving Battery Safety and Process Control with High-Speed X-ray Micro-CT

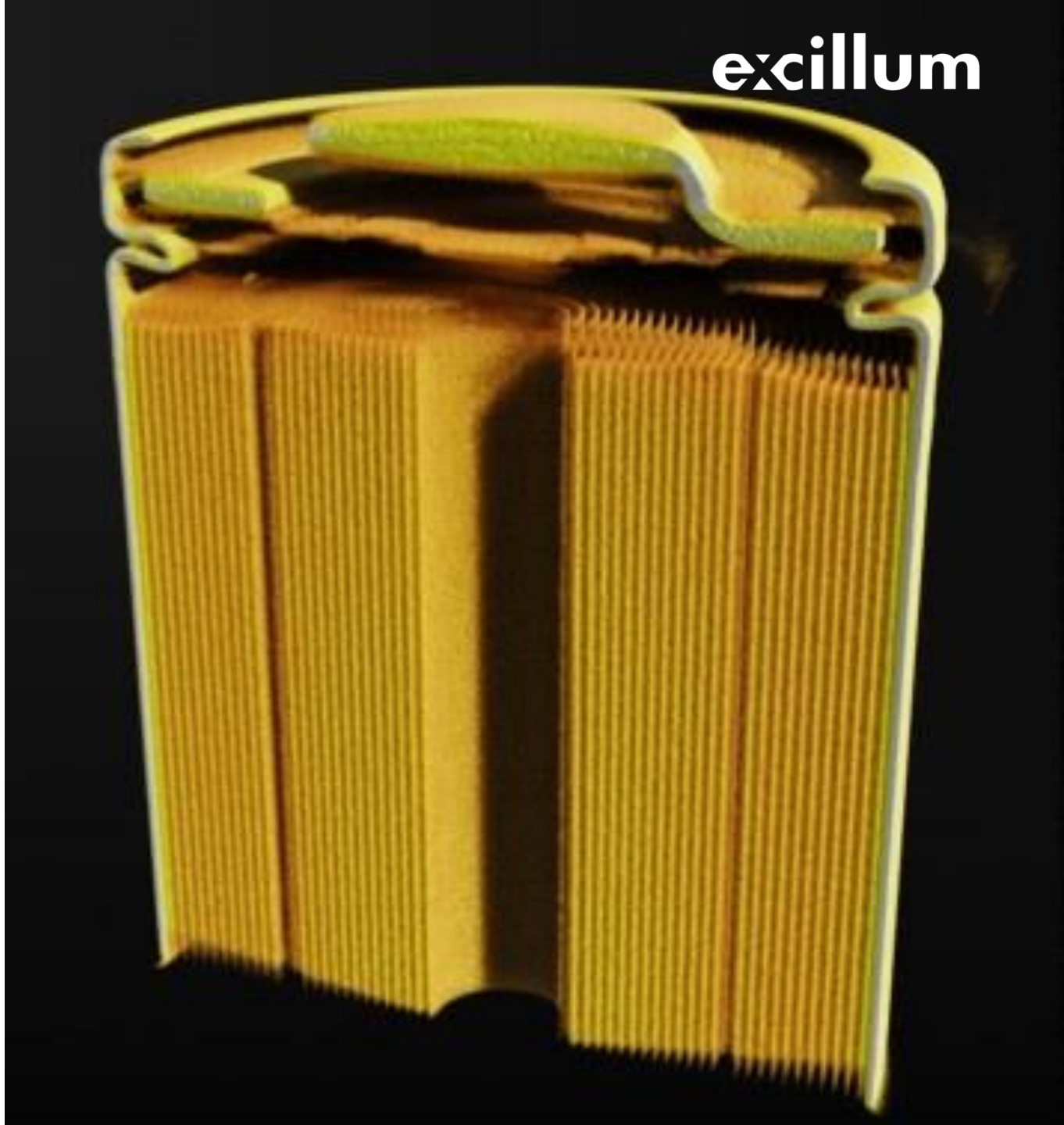
Dr. Till Dreier
Dr. Simona Laza

Battery Tech Expo Gothenburg
10th October 2024

excillum

Outline

- Excillum introduction
- Potential of battery CT
- High-speed battery CT with MetalJet E1+
- Process control with full battery CT
- Battery research with nano-CT
- Collaborations and partnerships
- Demo capability



The source for X-ray innovation

Entirely devoted to advanced microfocus and nanofocus X-ray sources

… (and some pure e-beam sources)

Based in Stockholm, Sweden

Established 2007

80+ colleagues

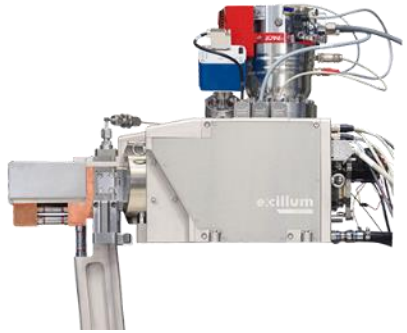
- 55% in R&D
- >10 nationalities

Our technology and product lines

MetalJet

World's brightest microfocus X-ray source

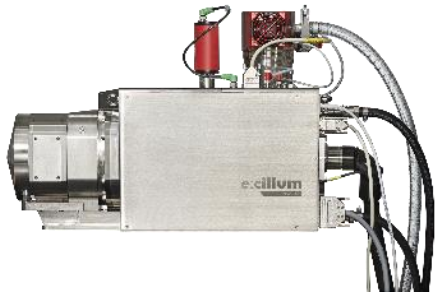
Liquid metal-jet anode and advanced electron beam technologies

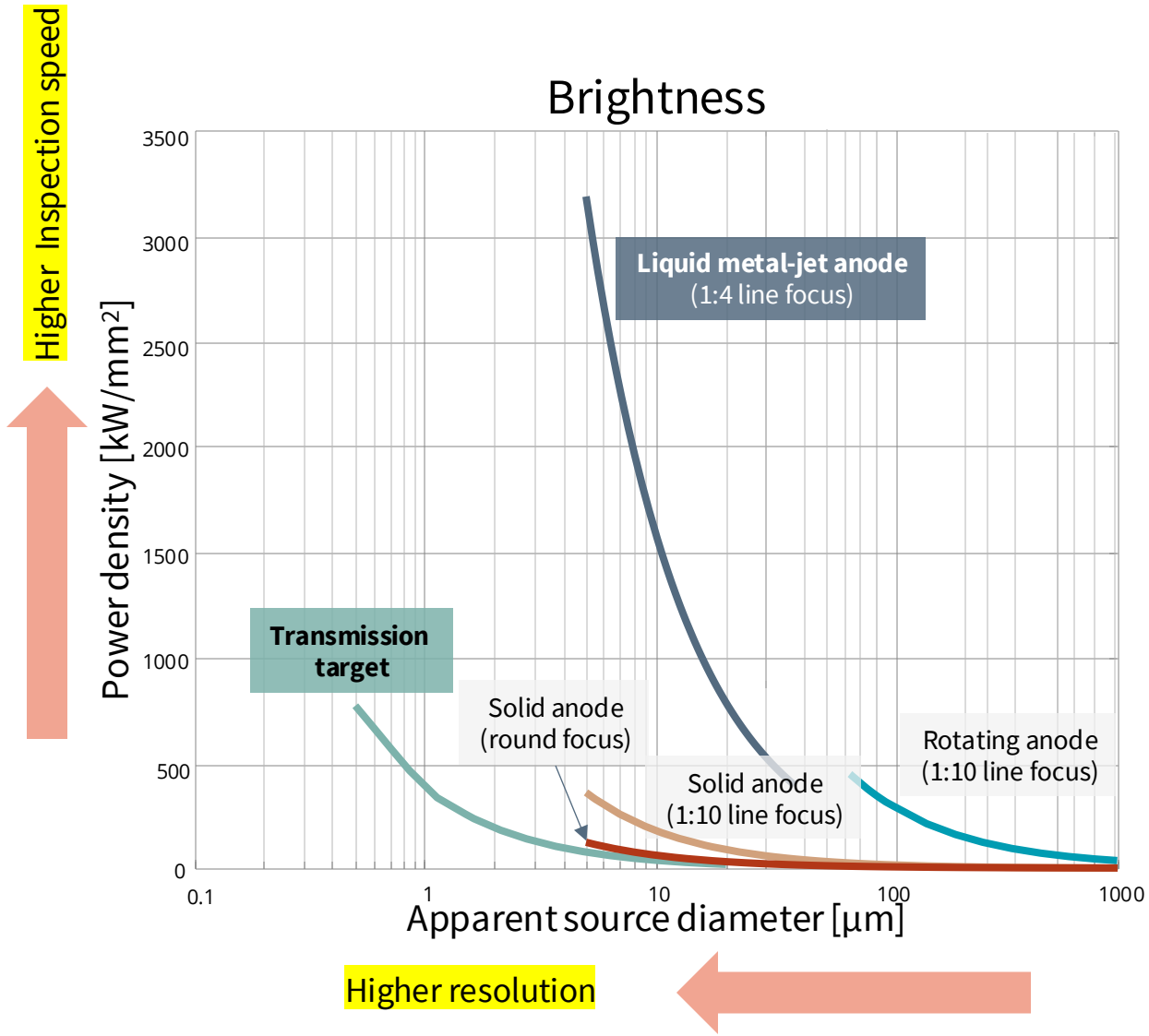


NanoTube

World's smallest X-ray nanospot

Advanced electron beam technology

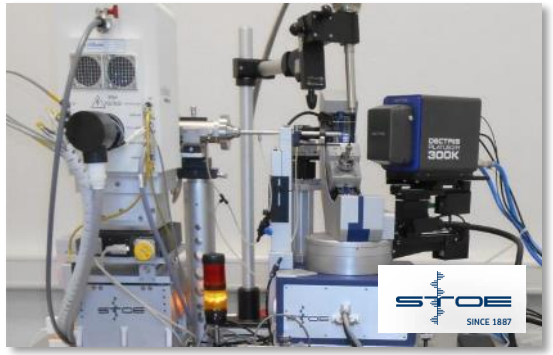




Analytical X-ray OEM partners

- our main business since 2011

X-ray sources for our partners' state-of-the art analytical systems typically using SCD, SAXS or HAXPES methods in biology, chemistry & material sciences, and high-tech manufacturing quality assurance.



X-ray imaging OEM partners

- a growing business since 2020

X-ray sources for our partners' high-speed extreme-resolution radiography, computed tomography (CT) or phase-contrast imaging systems for use in research and high-tech manufacturing quality assurance.

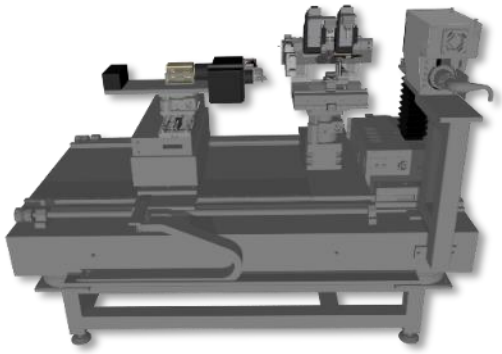
Rigaku

Presented at JASIS 2024

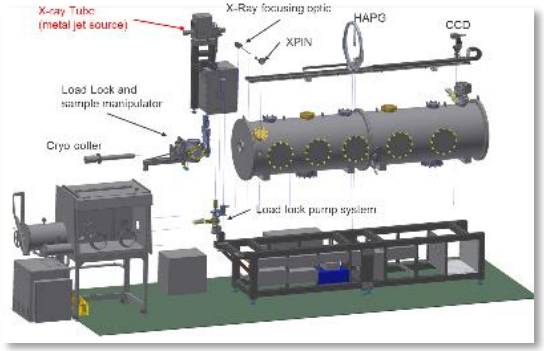
Custom experimental systems

- our original business, and the most advanced users

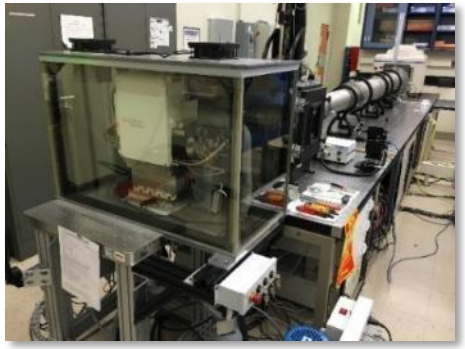
We support researchers who build their own experimental systems based on our X-ray source, and work with partners if they require help to design and build custom systems.



Multi-modal microscope
Würzburg University / Fraunhofer Institute
Germany



X-ray emission spectroscopy system
Max Planck Institute
Germany

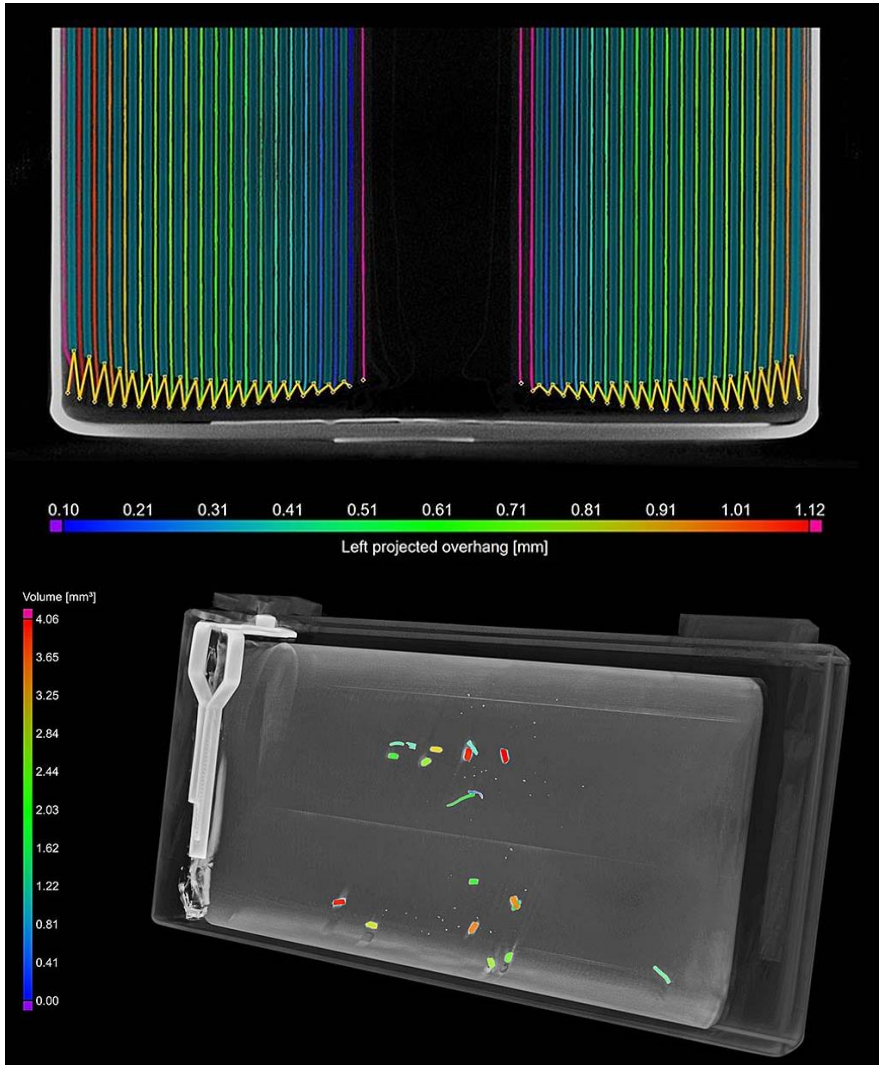


SAXS system
National Institute of Standards (NIST)
USA

Phase-contrast imaging system
Custom system by Proto
Johns Hopkins university
USA

Potential of battery CT

Potential of battery CT



https://www.qualitymag.com/articles/98283-how-ct-quality-analysis-of-ev-batteries-can-help-address-demand-and-performance

Quality MAGAZINE

CHANNELS NEWS MARKETS MEDIA EVENTS INFOCENTERS PRODUCTS DIRECTOR

TEST & INSPECTION

Test & Inspection

How CT Quality Analysis of EV Batteries Can Help Address Demand and Performance

Higher volumes of new batteries and faster turnaround of recycled materials from those batteries—along with testing of used and repurposed ones—demand the most efficient quality-inspection approaches possible.

By Dr. Daniela Handl

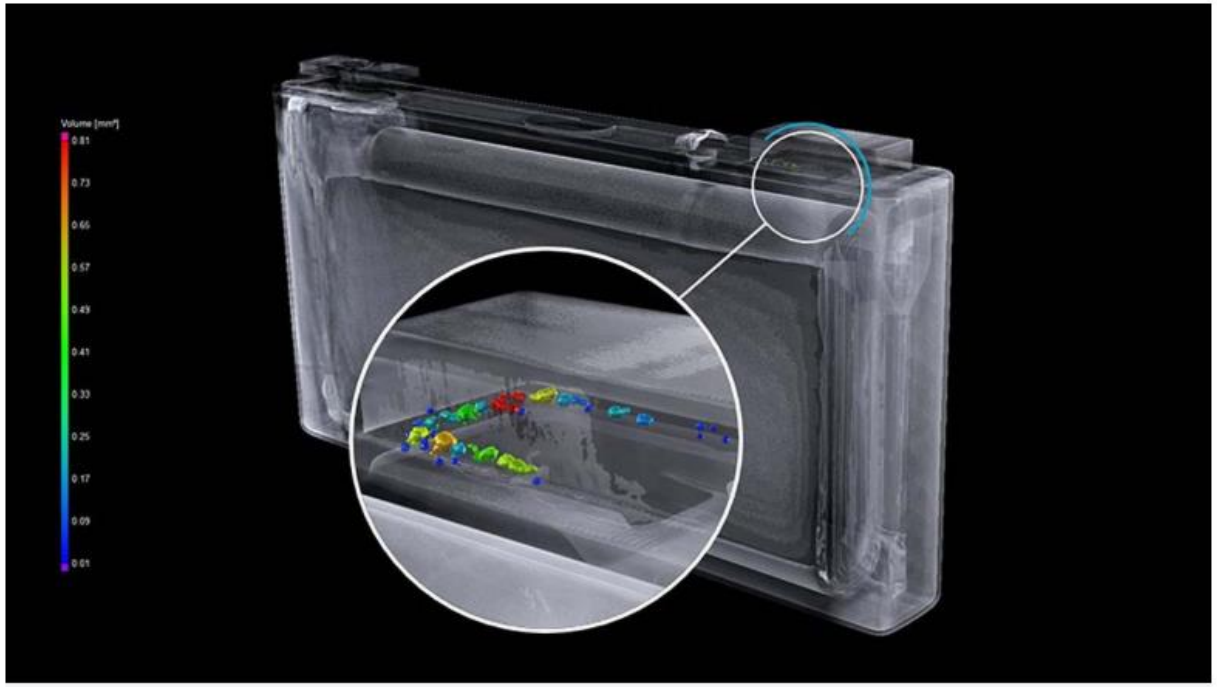
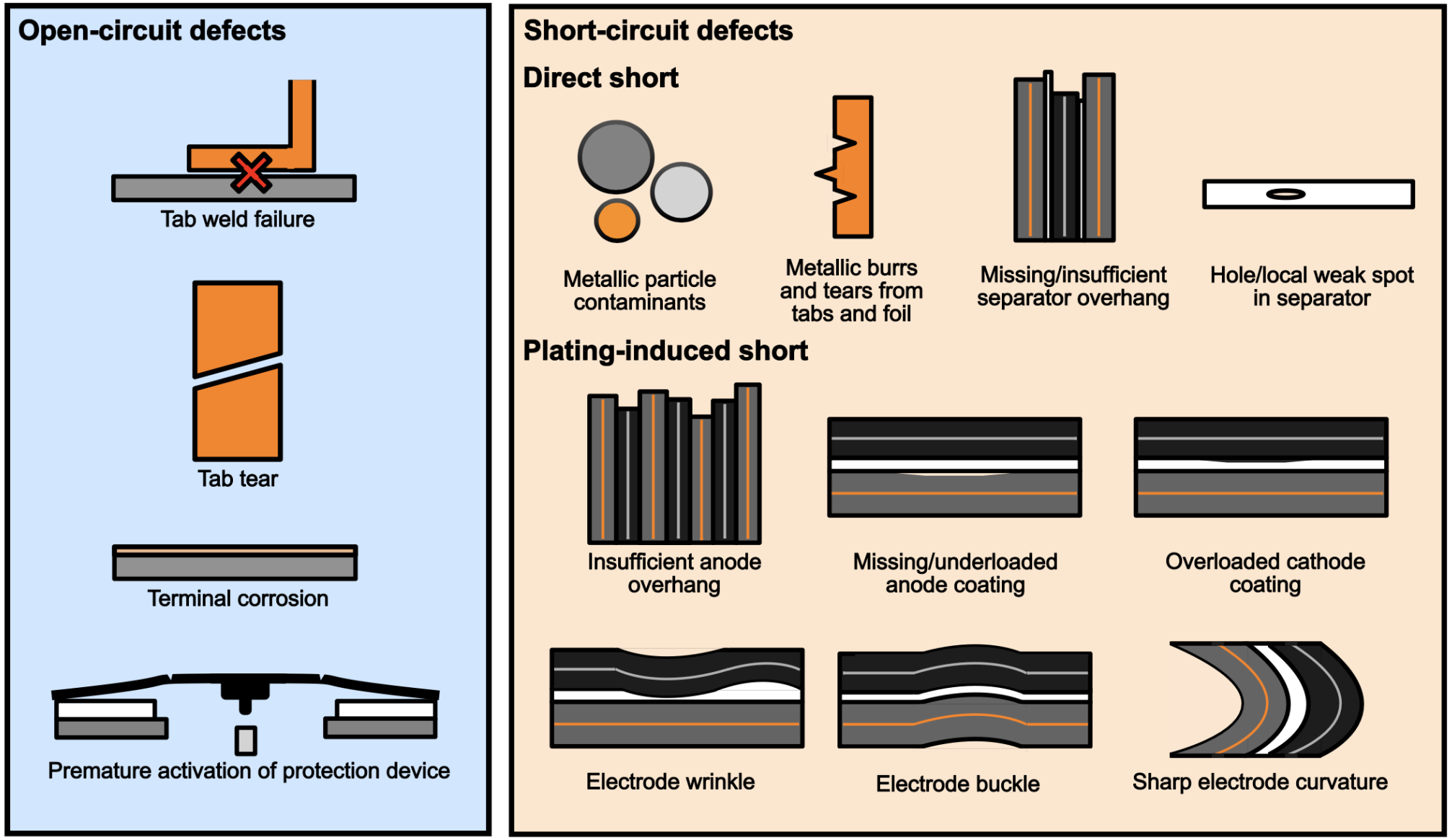


Image courtesy of Volume Graphics, a Hexagon company. Scan courtesy of Waygate Technologies.

Battery defects

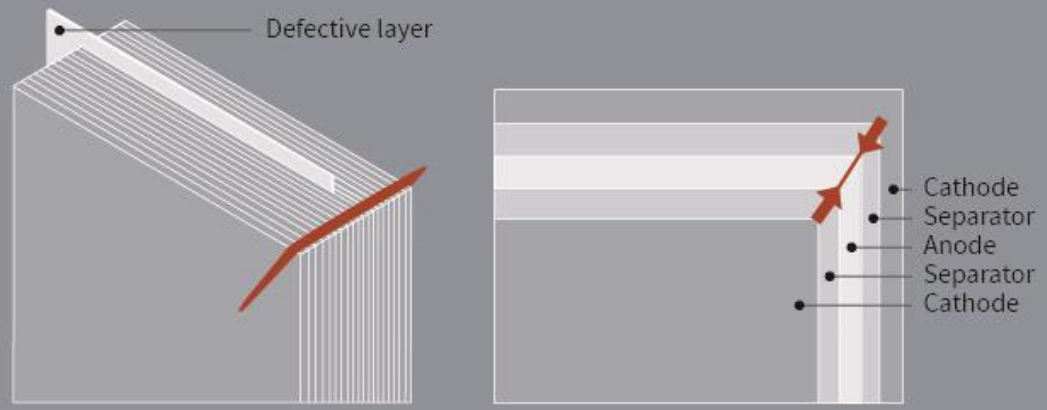


Slide provided by Glimpse: www.glimp.se

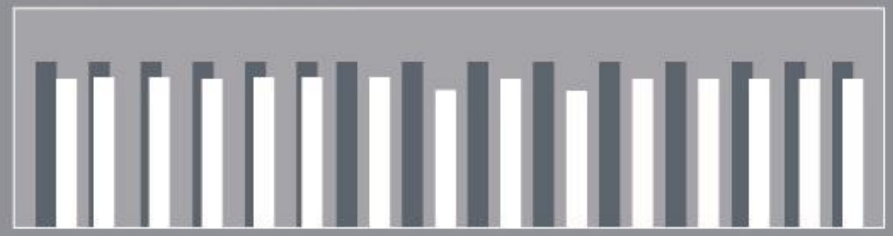
2D imaging vs CT scanning

Conventional 2D inspection

Inspection with corner X-ray image



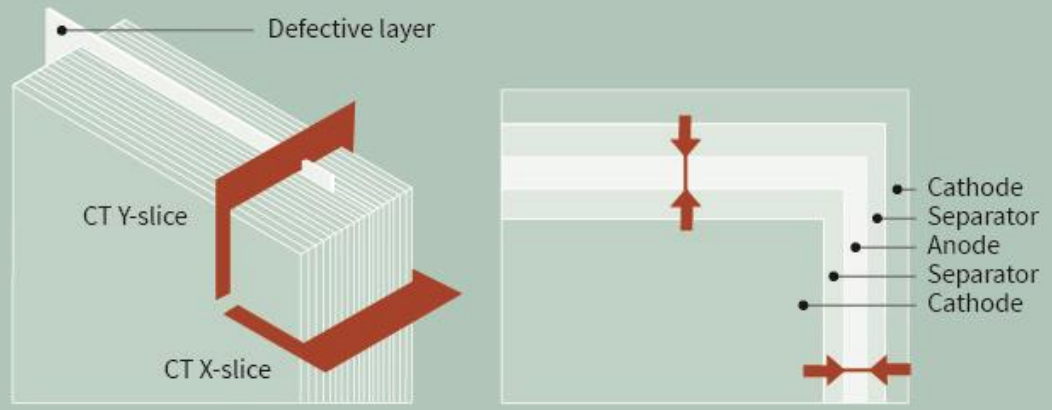
2D inspection image of corner



Due to the limitations of 2D X-ray, automatic inspection will not generate reliable data.

High-speed 3D inspection

Inspection of cross-sectional images in X and Y direction

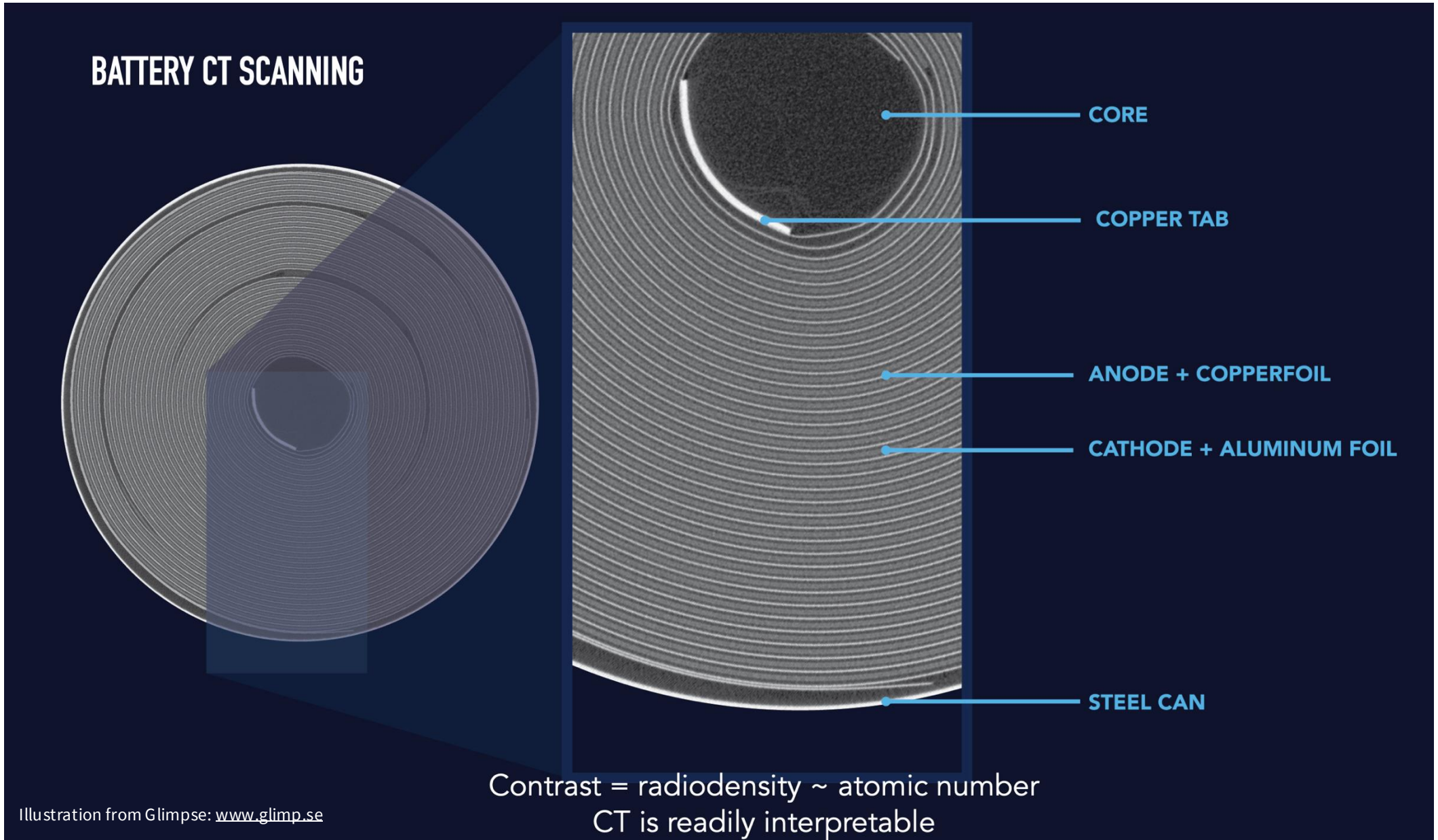


Y-slice CT inspection image
Anode/cathode overhang detection

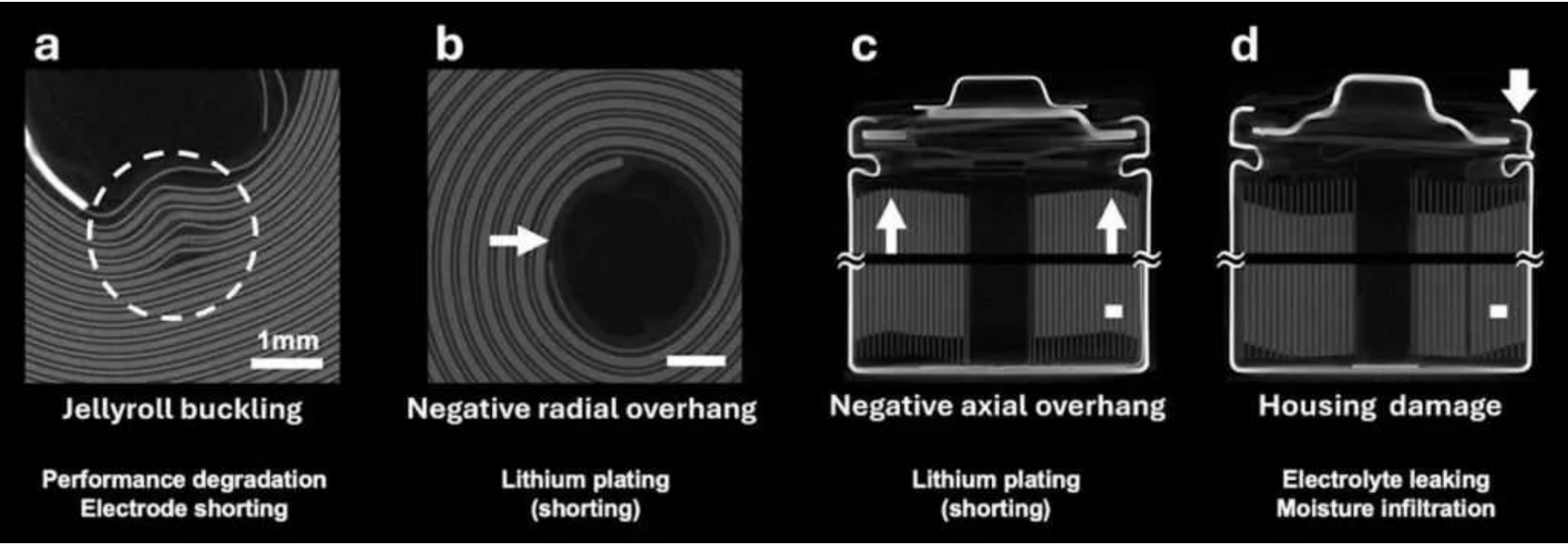
X-slice CT inspection image
Anode/cathode misalignment detection

CT-inspection generates 3D volume data for automatic inspection with maximum reliability.

CT scanning of batteries

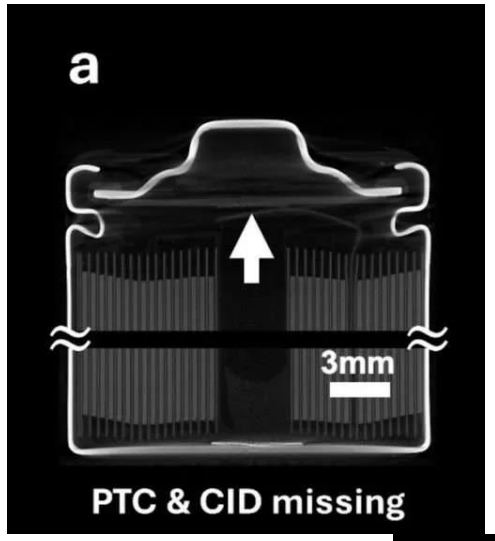


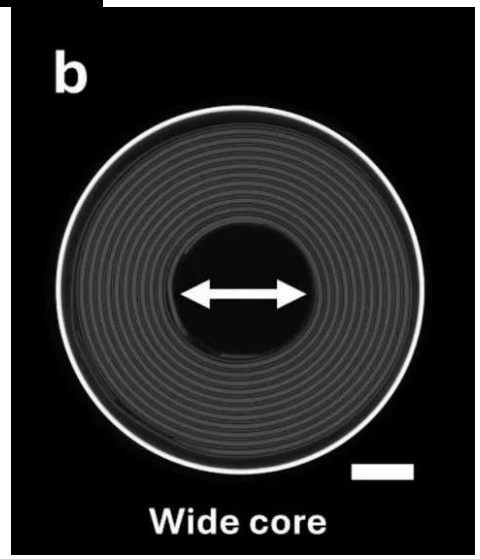
Defects identified by CT

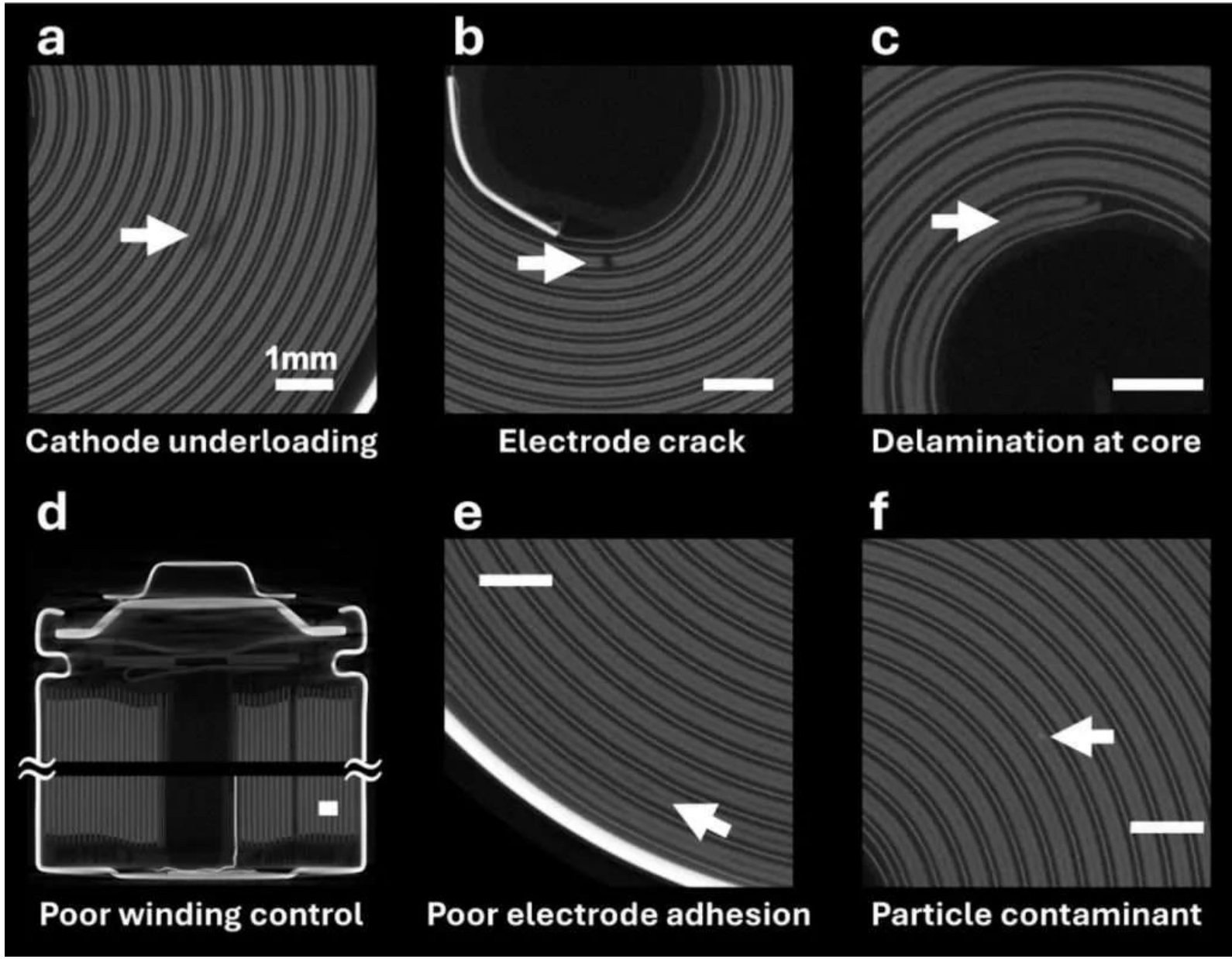


Images by Glimpse: https://www.batterydesign.net/using-ct-scanning-to-detect-battery-defects/

Defects identified by CT



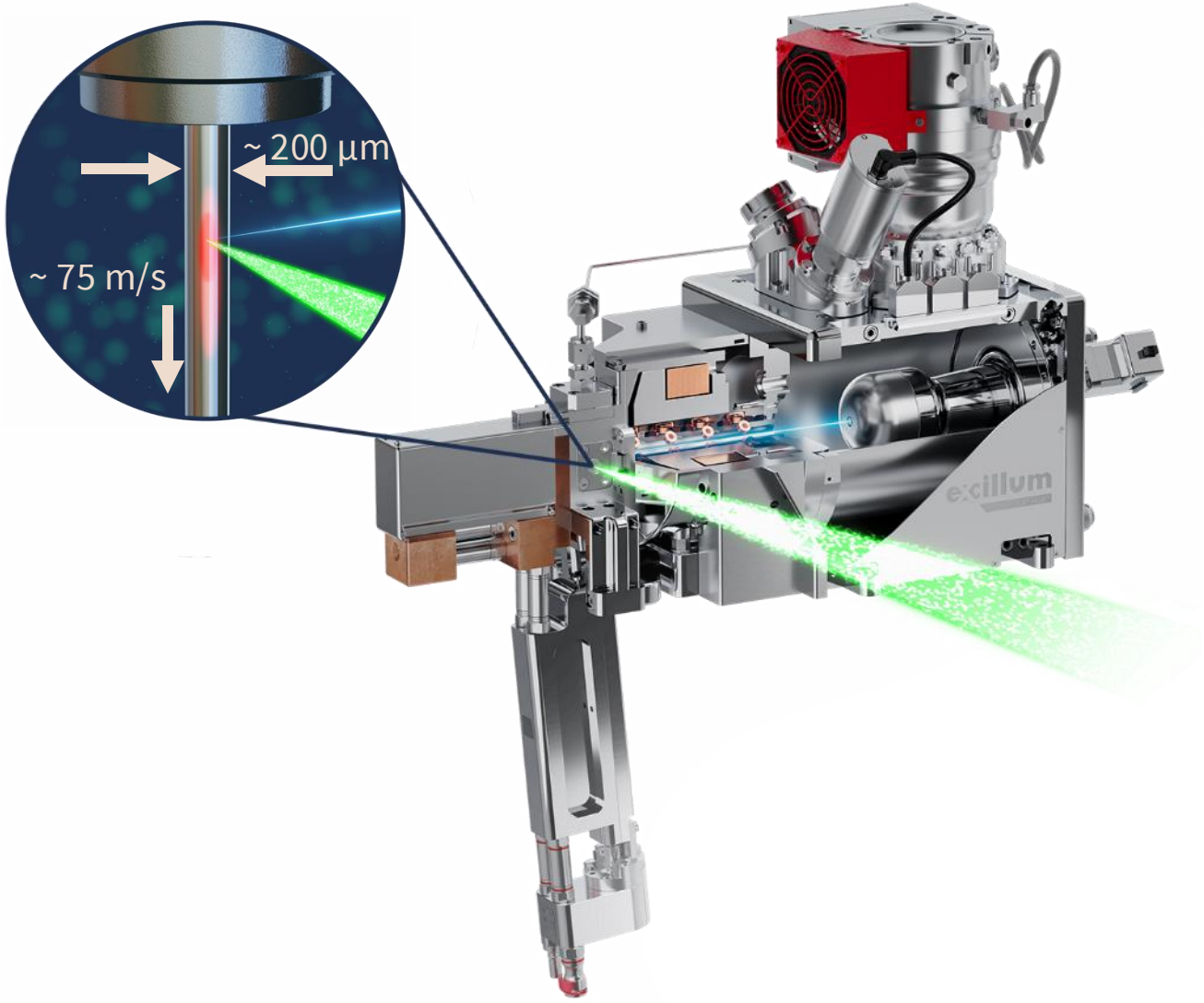


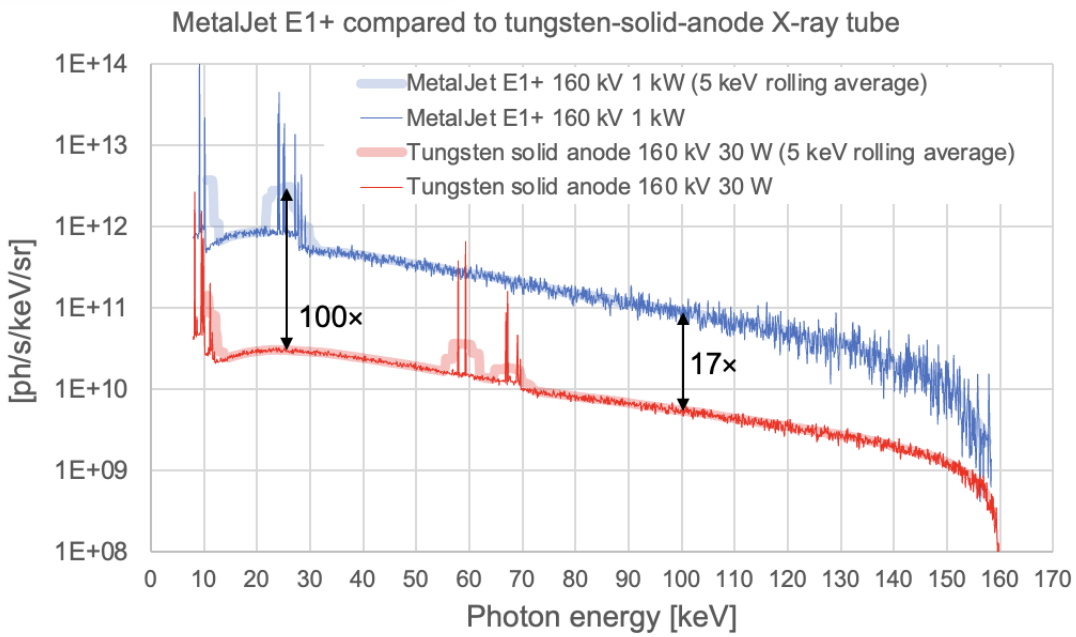


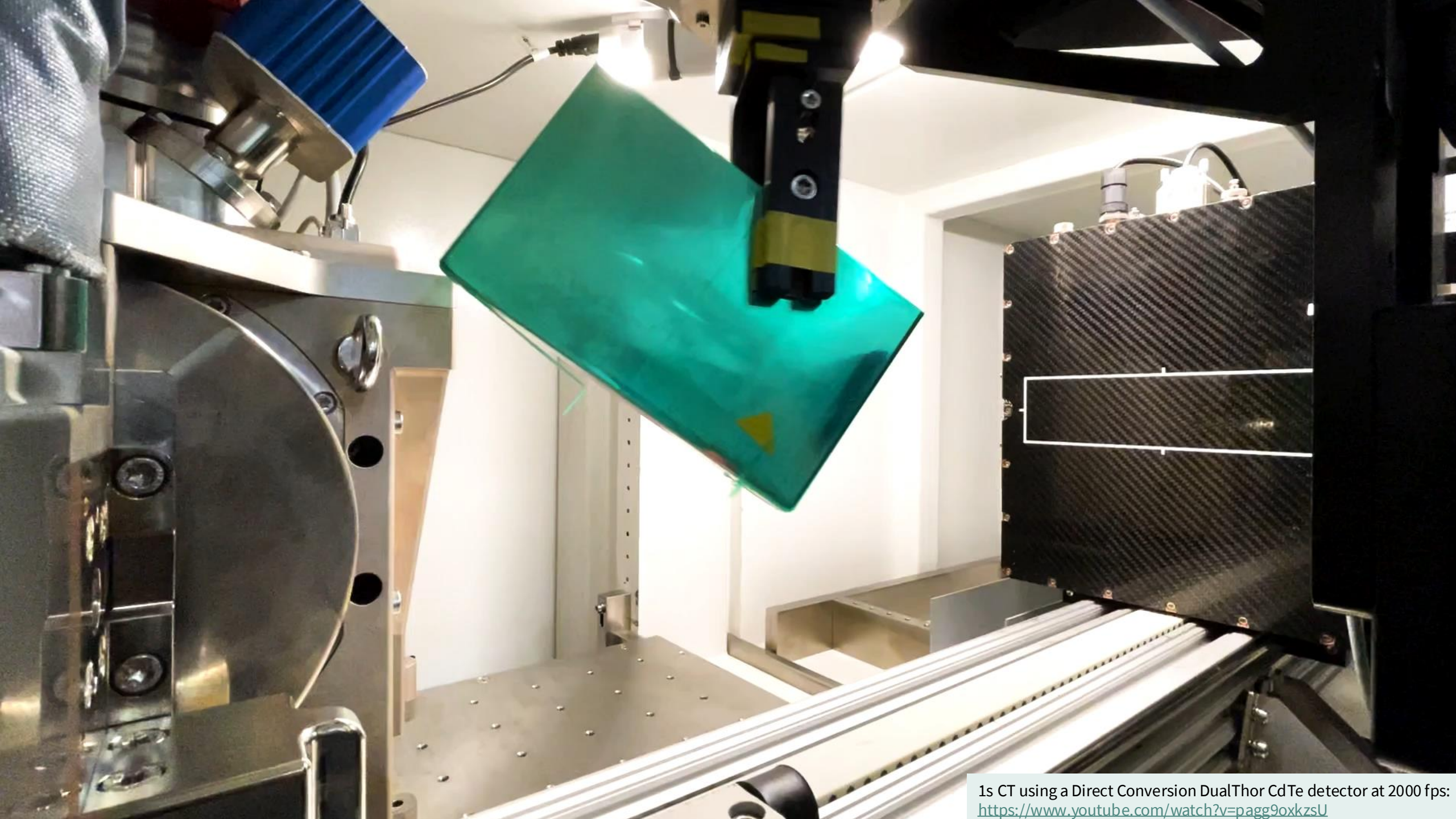
Images by Glimpse: https://www.batterydesign.net/using-ct-scanning-to-detect-battery-defects/

Excillum MetalJet E1+ for battery safety

The world’s brightest micro-focus X-ray source



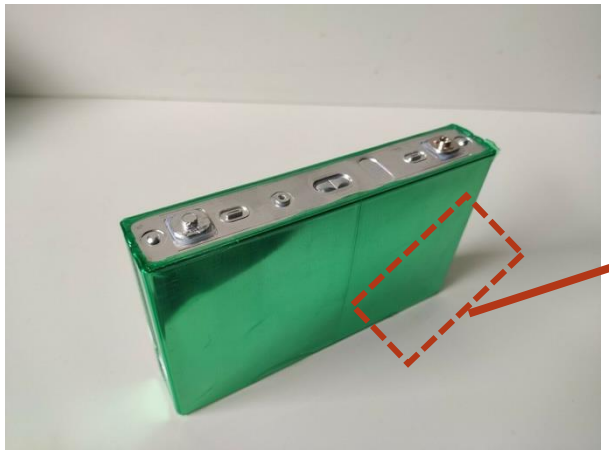


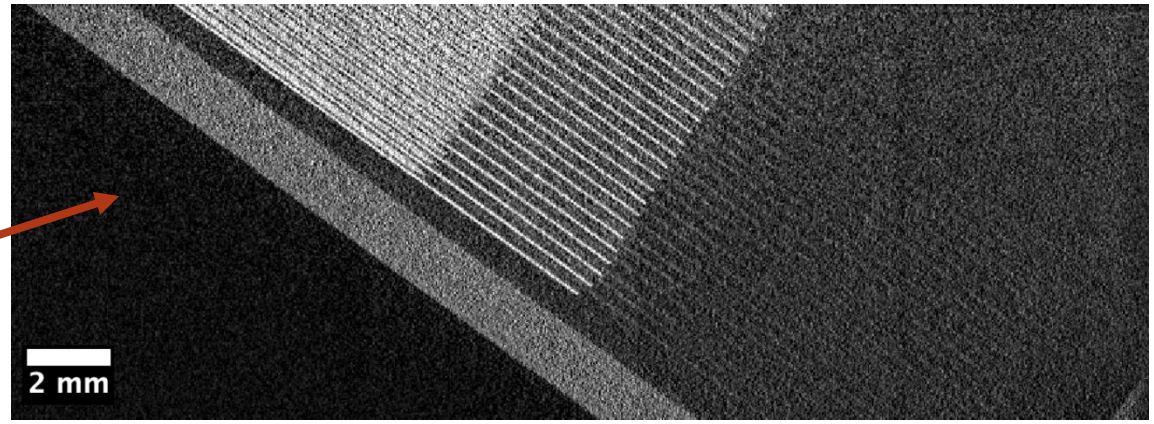


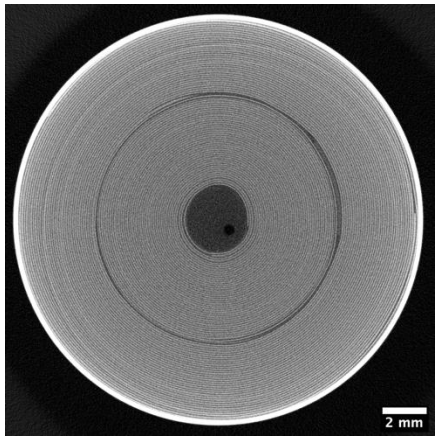
1s CT using a Direct Conversion DualThor CdTe detector at 2000 fps:
https://www.youtube.com/watch?v=pagg9oxkzsU

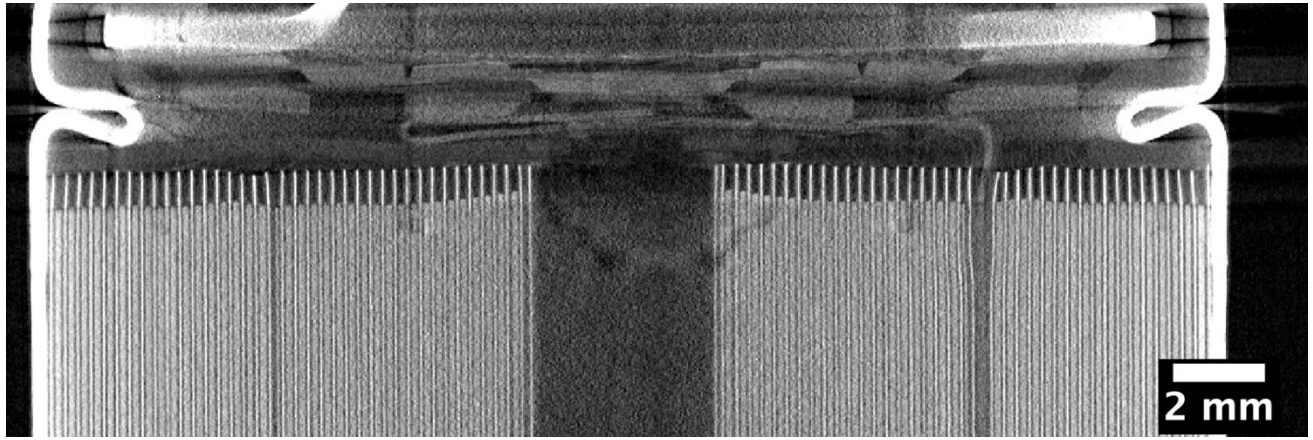
High-speed battery CT

- Overhang CT
  - Down to 0.5 s scan time
- Cylindrical cells
  - < 15 s helical-CT of 4680 cells
  - Overhang analysis
  - Particle detection
  - Layer defects
  - Winding defects
  - etc …









T. Dreier, et al., "*In-line and at-line battery CT enabled by MetalJet sources*". eJNDT, 2024: https://www.ndt.net/search/docs.php3?id=29240

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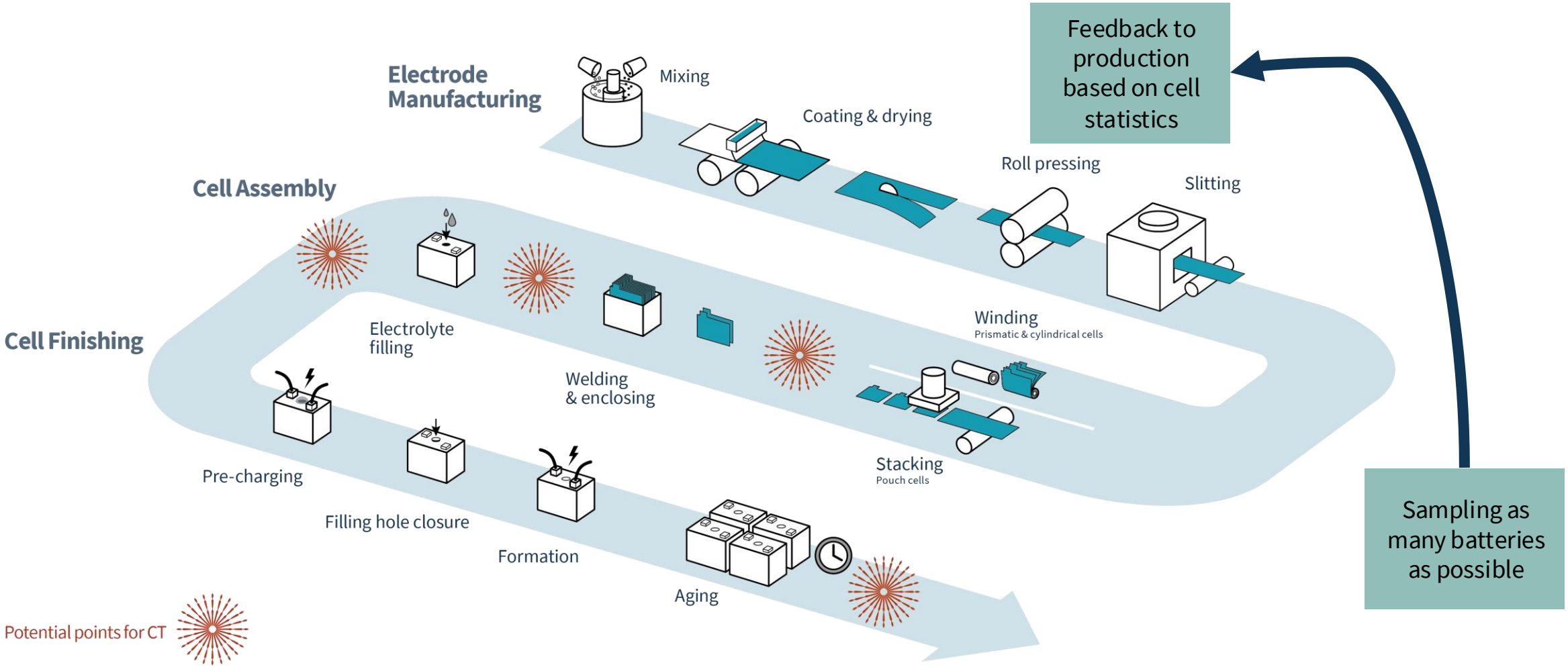
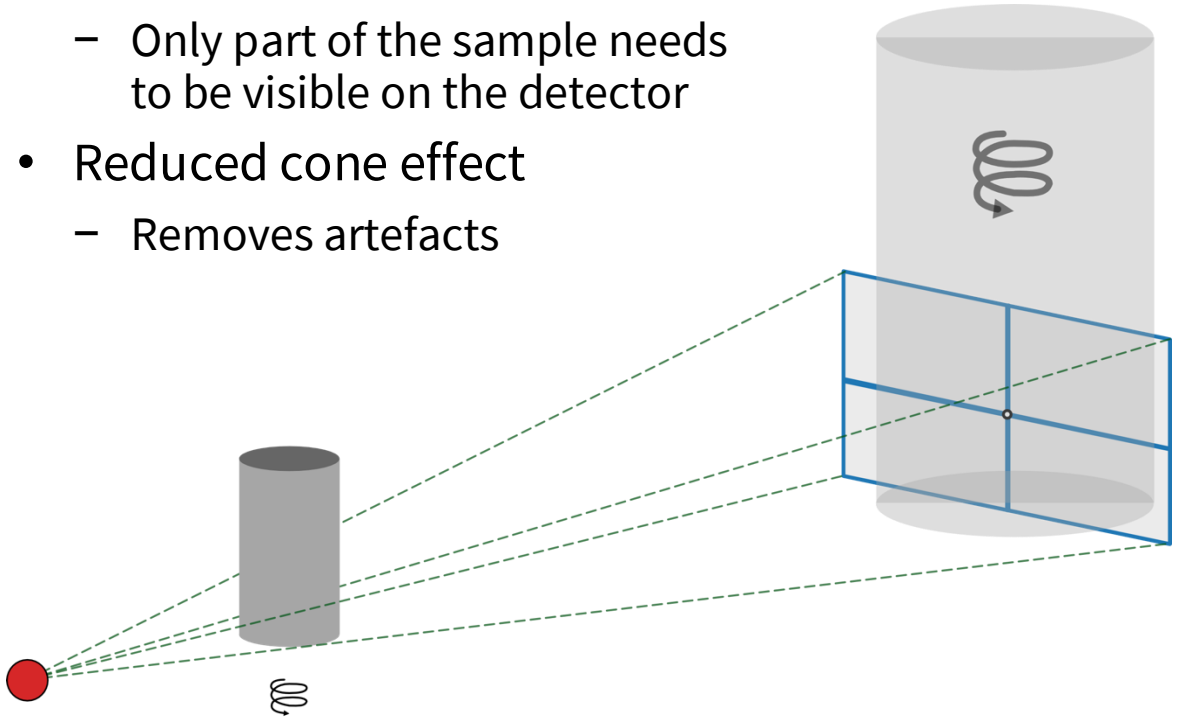
Process control

Process control through at-line full cell scanning

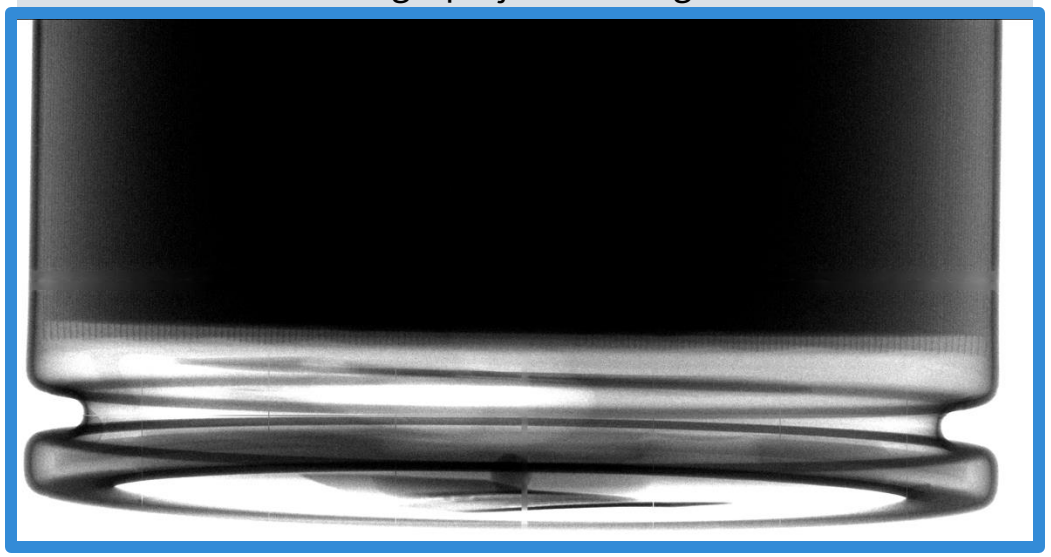


Helical CT

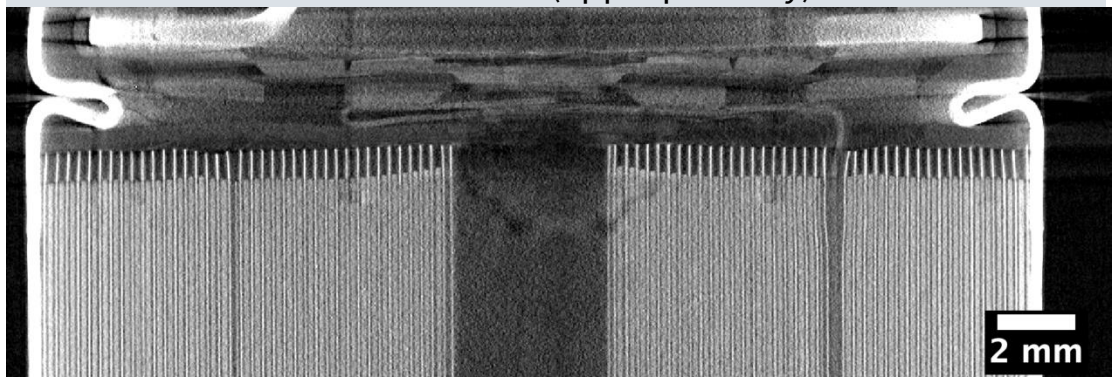
- Spiral motion instead of circular motion
- Allows more magnification
  - Only part of the sample needs to be visible on the detector
- Reduced cone effect
  - Removes artefacts



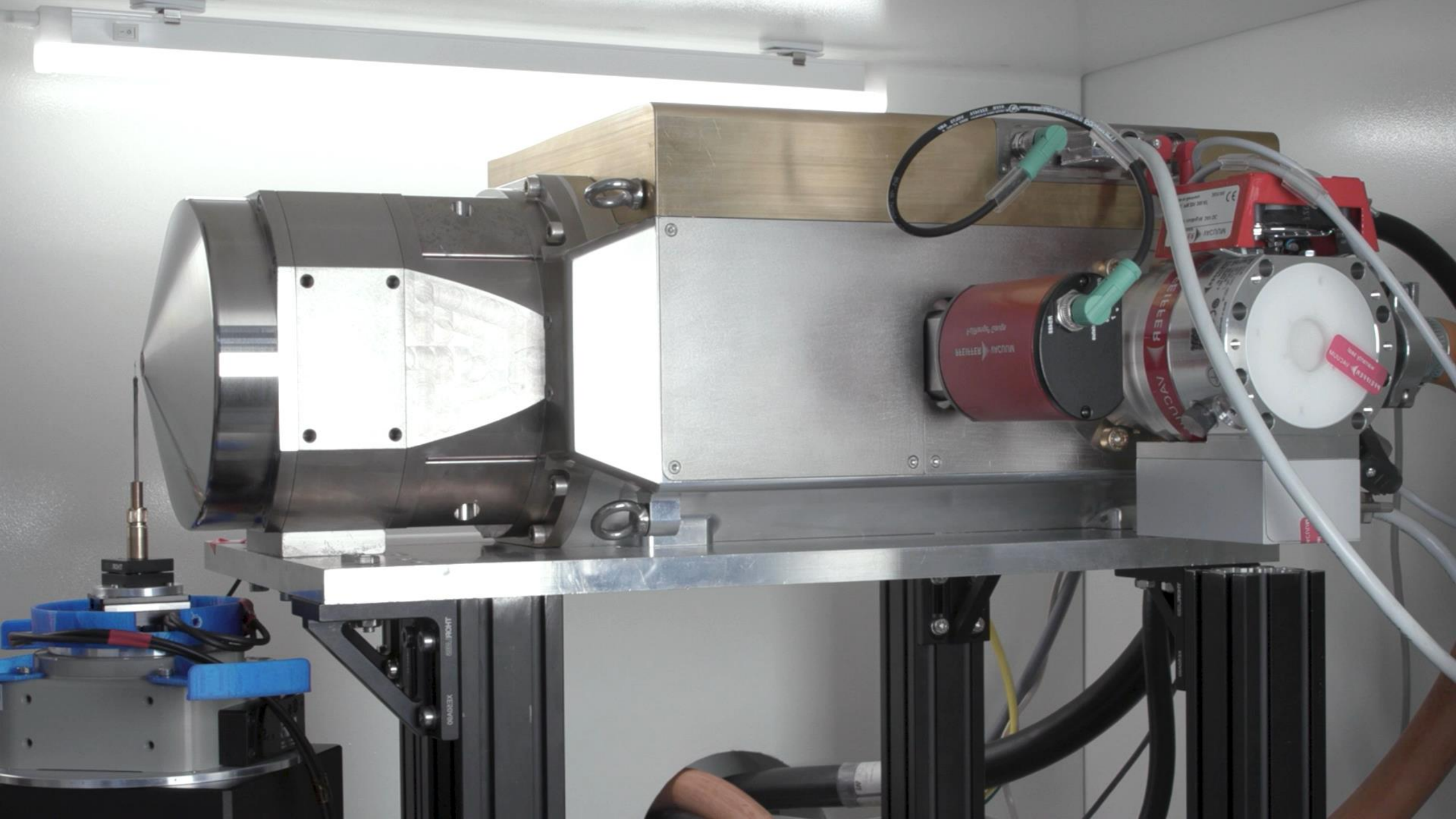
Single projection image



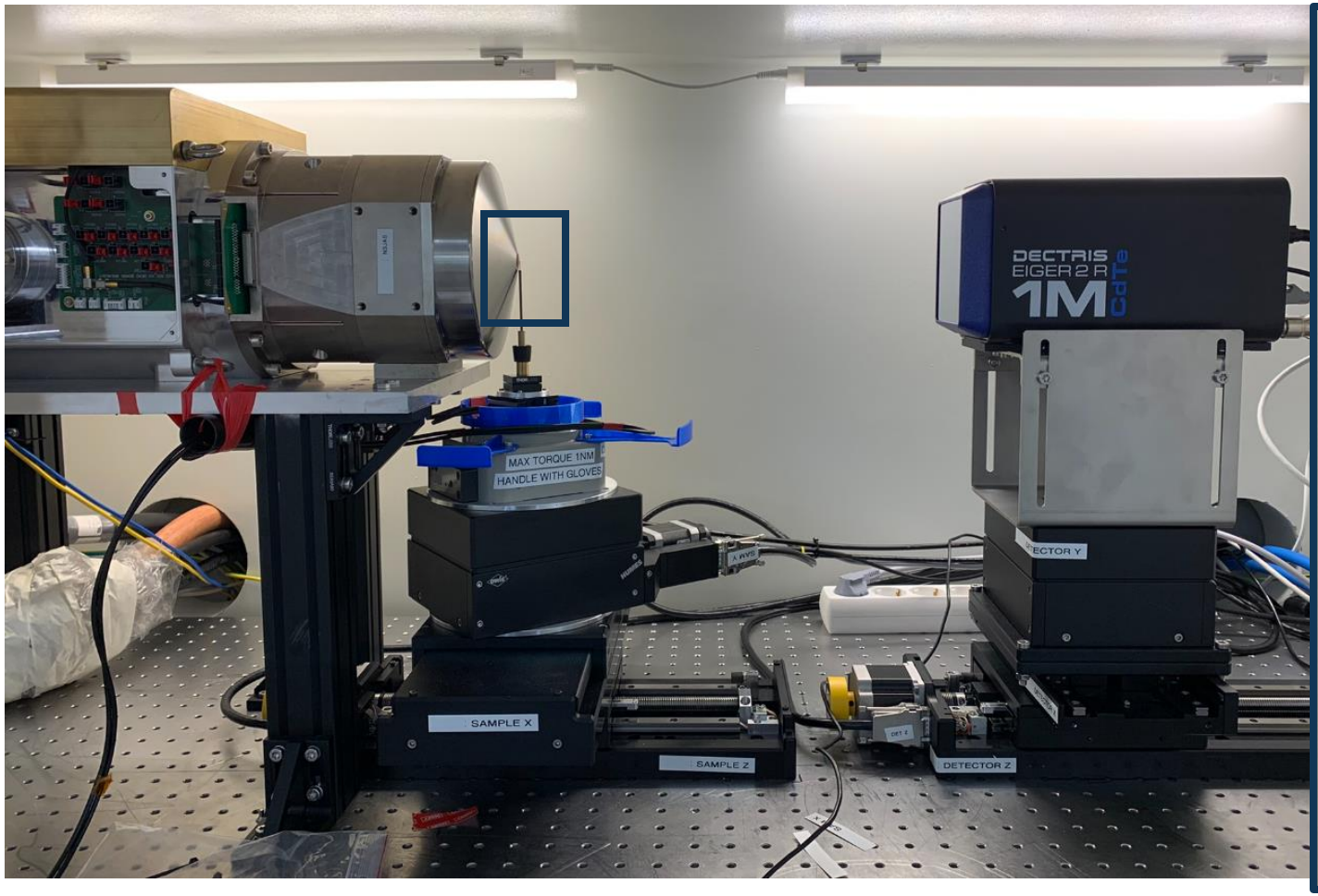
Reconstruction (upper part only)



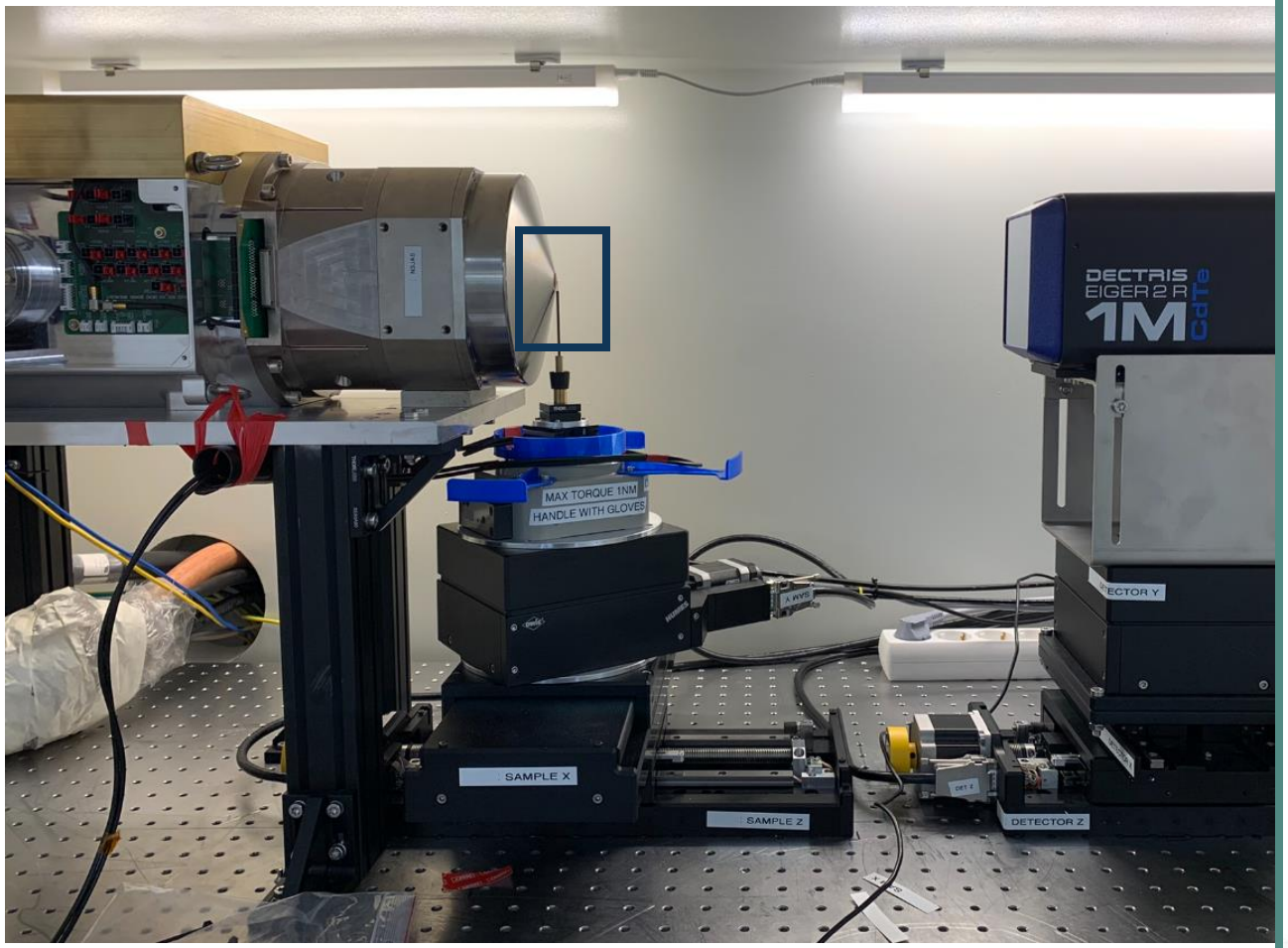
X-ray nano-CT for battery research

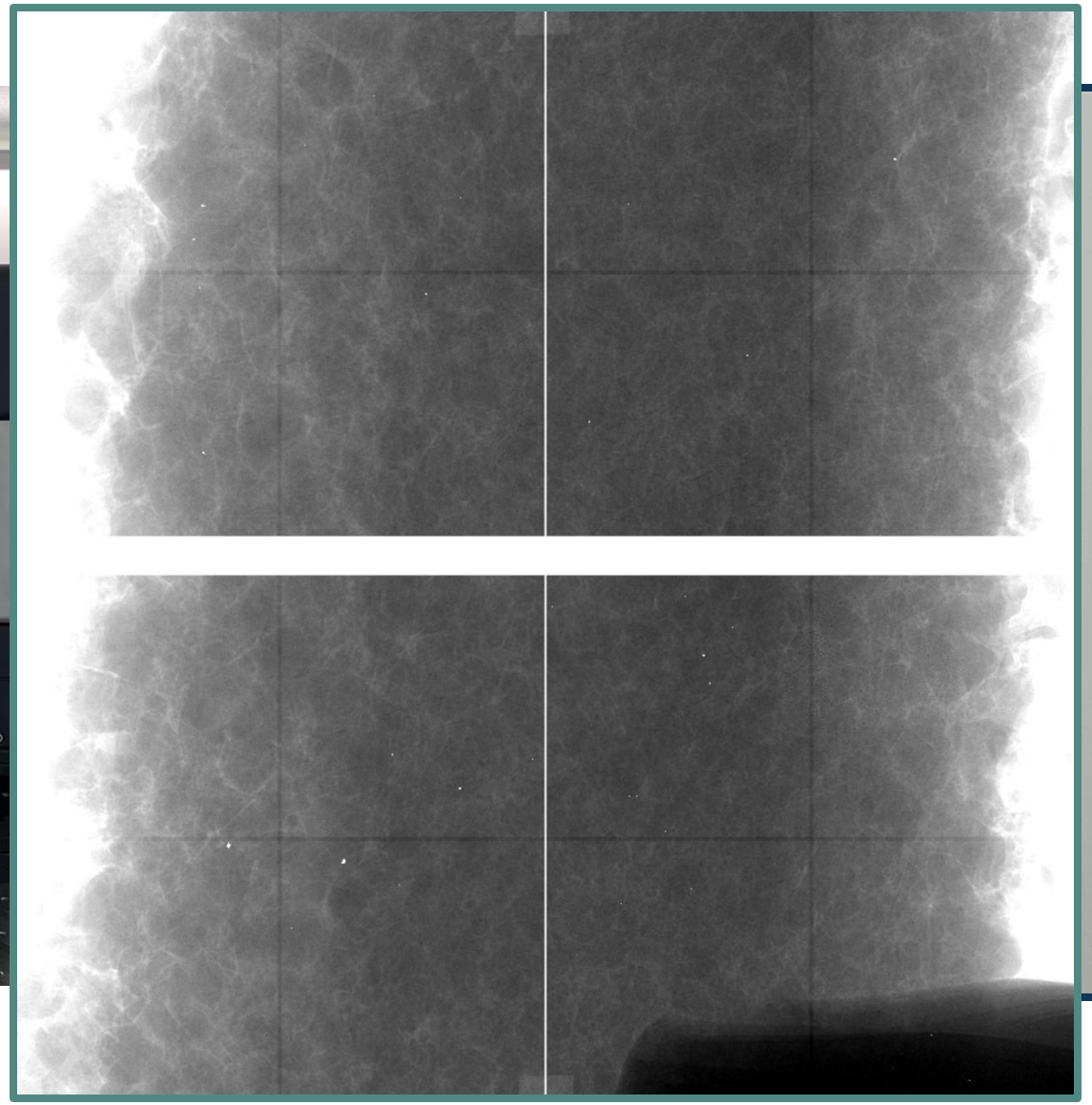


Nano-CT of a battery cathode

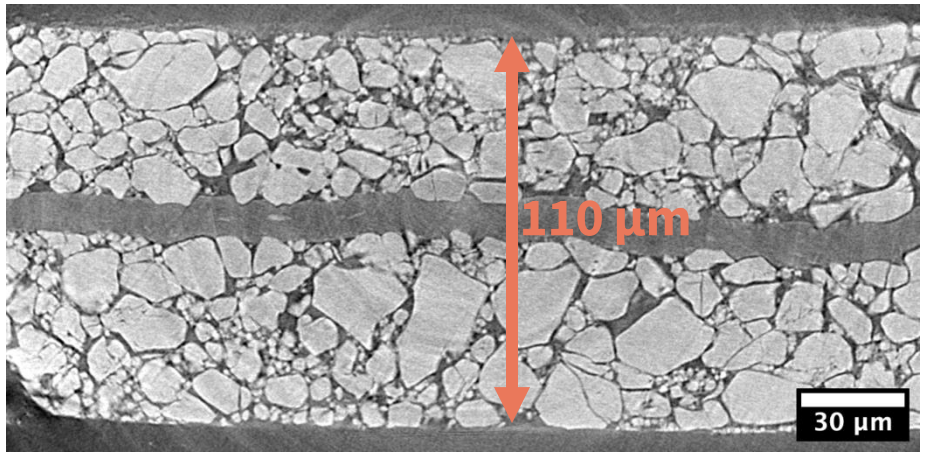


Nano-CT of a battery cathode

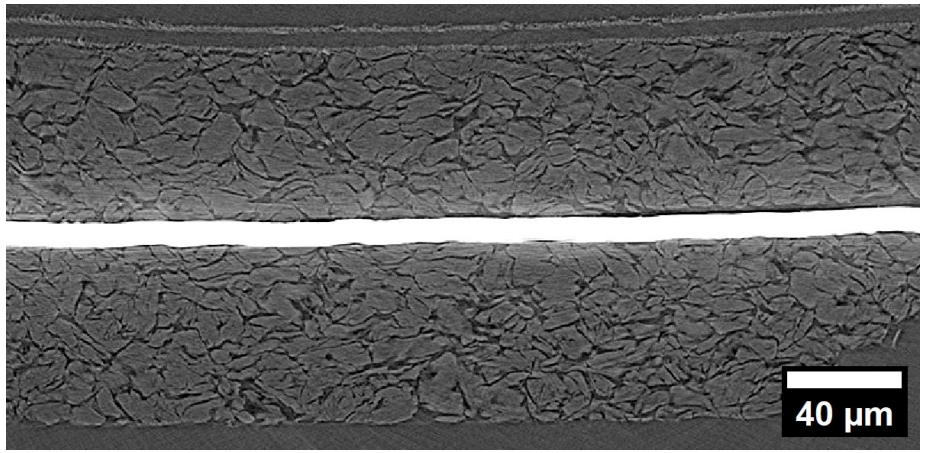




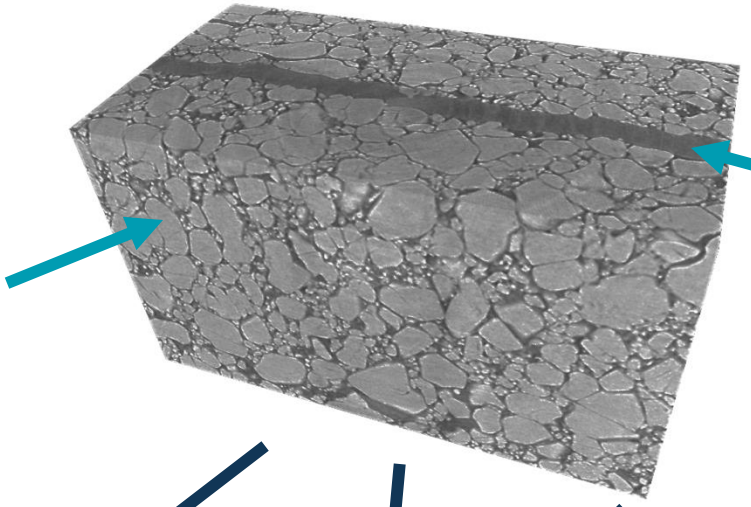
Imaging of anode and cathode layers



Battery cathode - mostly Cobalt (50 µm per side) with an Aluminium collector in the middle (10 µm).



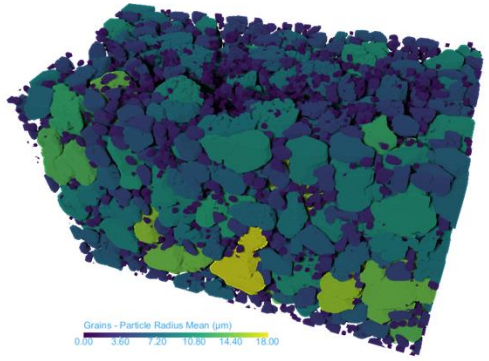
Battery anode - mostly Graphite (50 µm per side) with a Copper collector in the middle (10 µm).



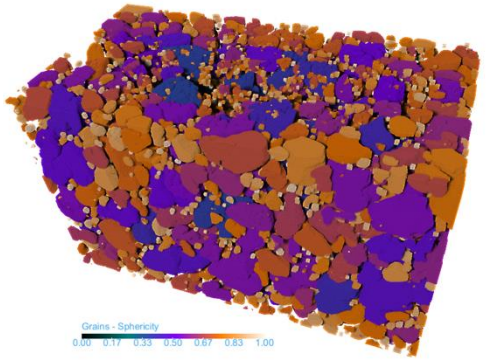
Cathode layer
LiCoO2
~50 µm

Aluminum collector
~10 µm

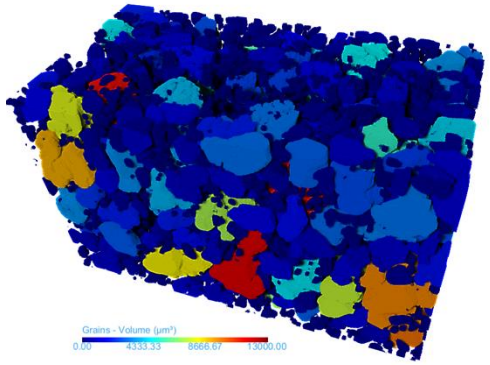
Particle radius



Sphericity



Volume



Excillum's Collaboration Interests

Member of European Industry Associations

BEPA Batteries European Partnership Association

Aeneas

Member of Swedish Competence Centers

Batteries Sweden BASE

NEUTRON AND X-RAY SCIENCE FOR INDUSTRIAL TECHNOLOGY TRANSITIONS

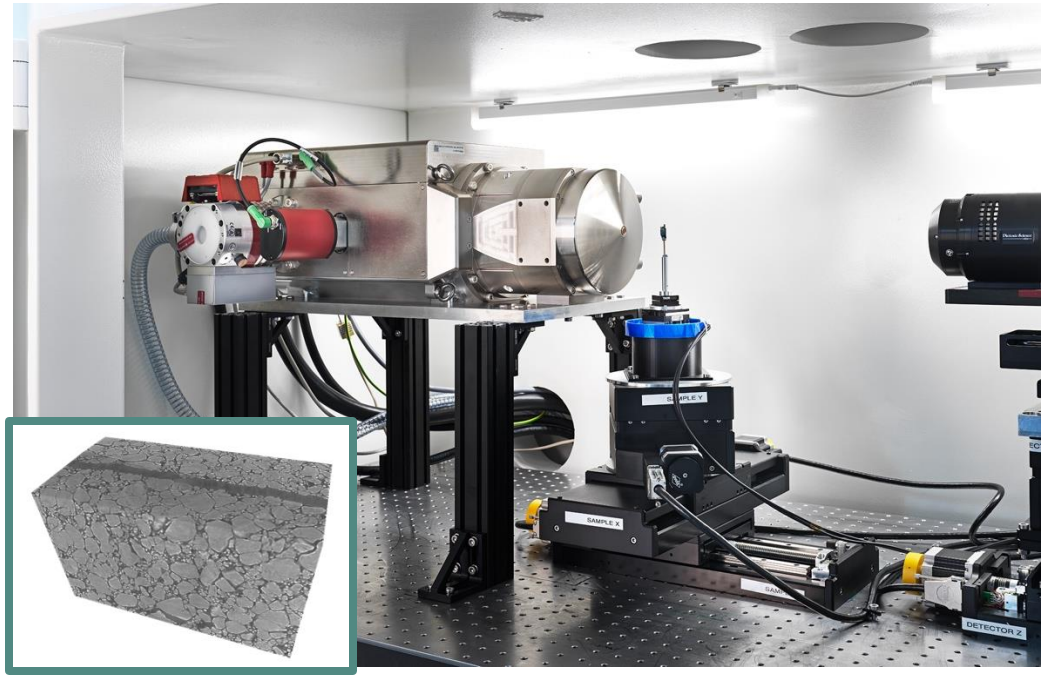
Excillum reinvest 25% of its sales in R&I.

Collaborative interests:

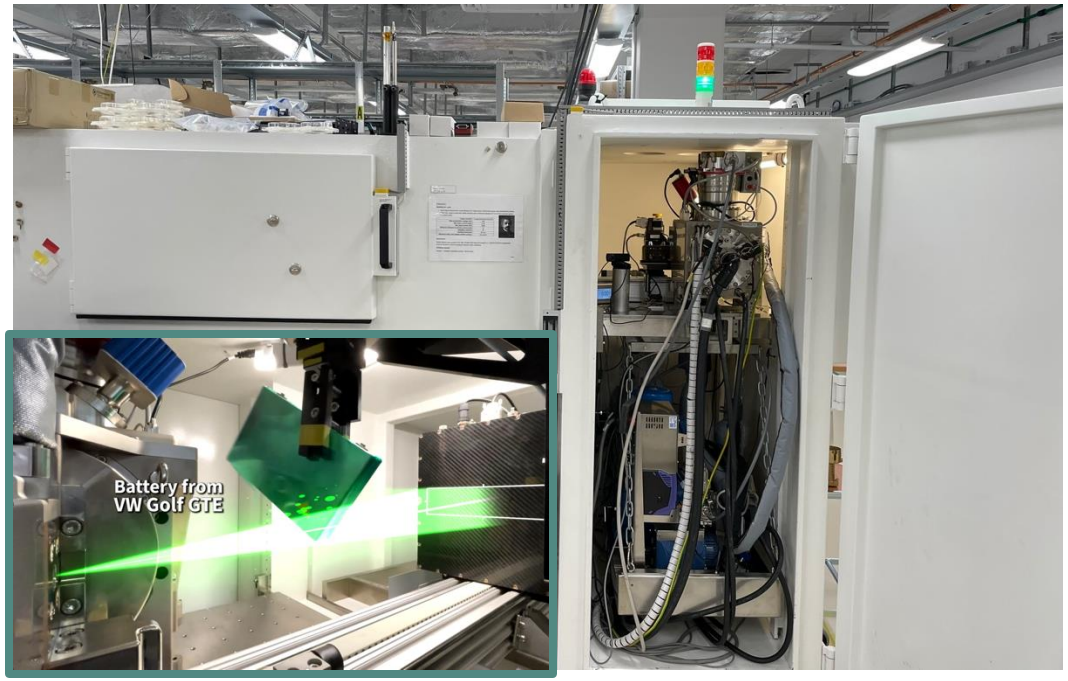
- Technology development and new market access
- Participation in Pilot lines
- Collaborative projects: *Horizon Europe, Eurostars, Chips JU, VINNOVA, Enenrgymindigheten, etc.*
- Commercial collaborations

Contact us for a demo

- Nano-CT setup with NanoTube N3 160 kV



- Micro-CT with MetalJet E1+ 160 kV



Contact us: till.dreier@excillum.com

The source for X-ray innovation

Dr. Simona Laza
Strategic Public Partnerships
simona.laza@excillum.com

Dr. Till Dreier
Application Scientist
till.dreier@excillum.com