Application of X-Ray Diffraction to CBP

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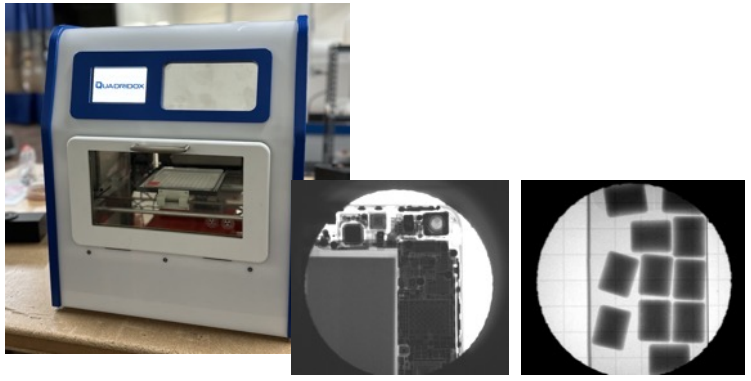
So what? Who cares?

- **Space**: Cargo screening/inspection
  - XRD is presently being evaluated by CBP by other companies. For example, at international mail facility at JFK and at southern border. One application is fentanyl.
- **Problems:** Decrease P_{FA}, allow increases in P_D, offer new secondary inspection technology. Stop prohibited items without increasing inspection time.
- **Solution:** Augment current solutions with XRD imaging
- **Results:** We've shown that XRD imaging can **reduce false alarms while maintaining throughput** in the checked baggage aviation security space. Moreover, we've been able to perform material characterization with tabletop systems
- **TRL:** 5-7 for checked baggage, Possible CBP applications: fentanyl/narcotic and ag/bio interdiction in international mail, expressed consignment packages, border crossings, and inbound flights

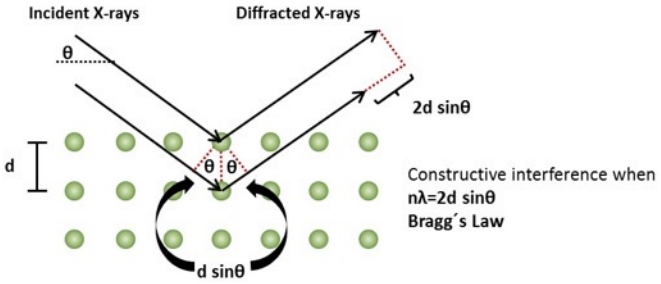
We are interested in collaborating with government to further develop systems, increase TRL, and prove efficacy. We'd like to work with equipment manufactures, and small businesses through all sorts of mechanisms. Please reach out!



XRD physics

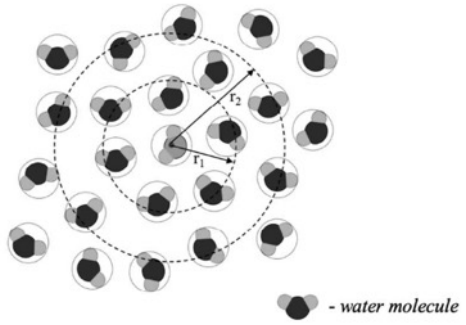
- Conventional X-ray transmission imaging provides information about an object's density by measuring X-rays that pass through the sample
- **X-ray diffraction** provides information about the atomic structure of an object by measuring the X-rays that bounce off the sample
- Coherent scatter from many scatterers interferes and produces an energy-and angle-dependent intensity distribution

XRD from lattice (crystal)



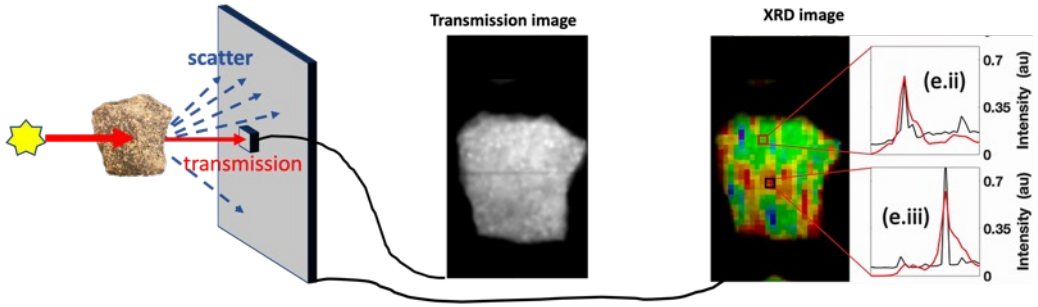
https://wiki.anton-paar.com/se-en/x-ray-diffraction-xrd/

XRD from coordination spheres (liquid)



Wolter (2018). X-Ray Diffraction Imaging: Technology and Applications, CRC Press.

XRD imaging



Stryker et al., Sci Rep, 11 10585 (2021)

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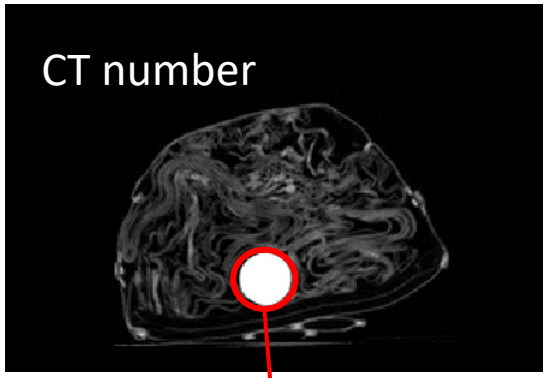
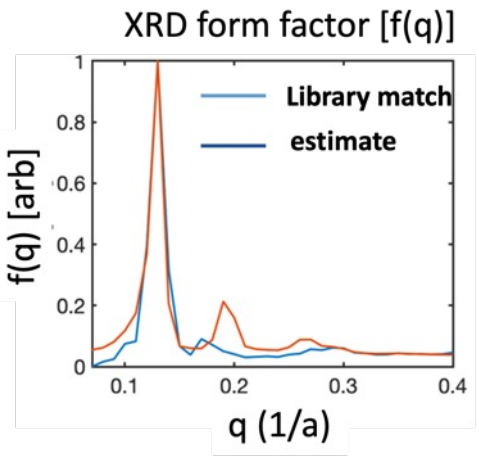
Checked baggage screening

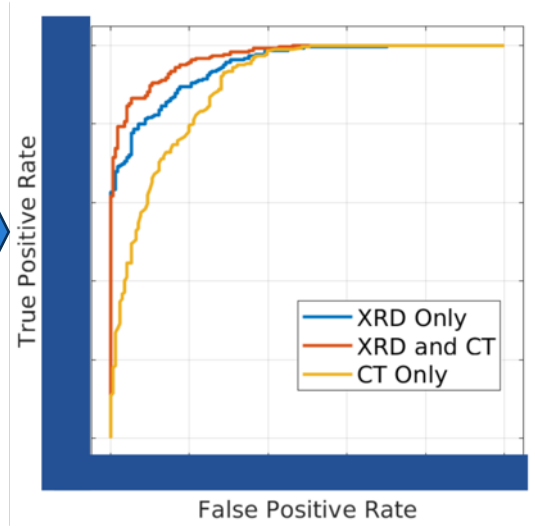
Quadridox offers a modular, vendor-agnostic system that can **resolve alarms anywhere in the tunnel at native EDS speeds**





- **Modular, compatible with AT/CT systems**
- **Full-tunnel imaging at speed**
- Uses only **off-the shelf components**
  - Dual view, dual energy transmission imaging
  - Photon-counting scatter detectors
  - Standard monoblock “CT” X-ray tube
- No moving parts (except belt, fans)
- Accommodates up to 100 x 60 cm bag dimensions
- Real-time scanning (currently 20 cm/s)
- Smaller (or similar) footprint compared to current EDS CT machines

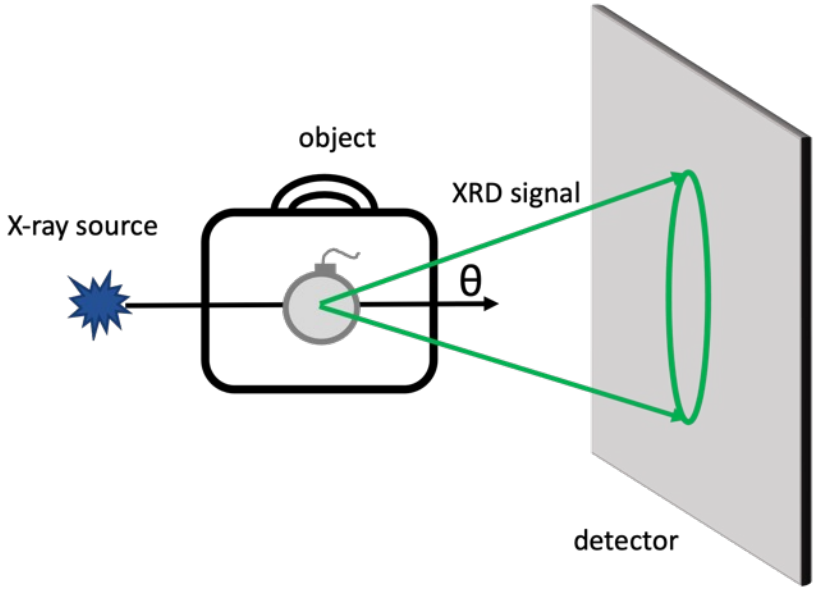
Promising results for false alarm reduction



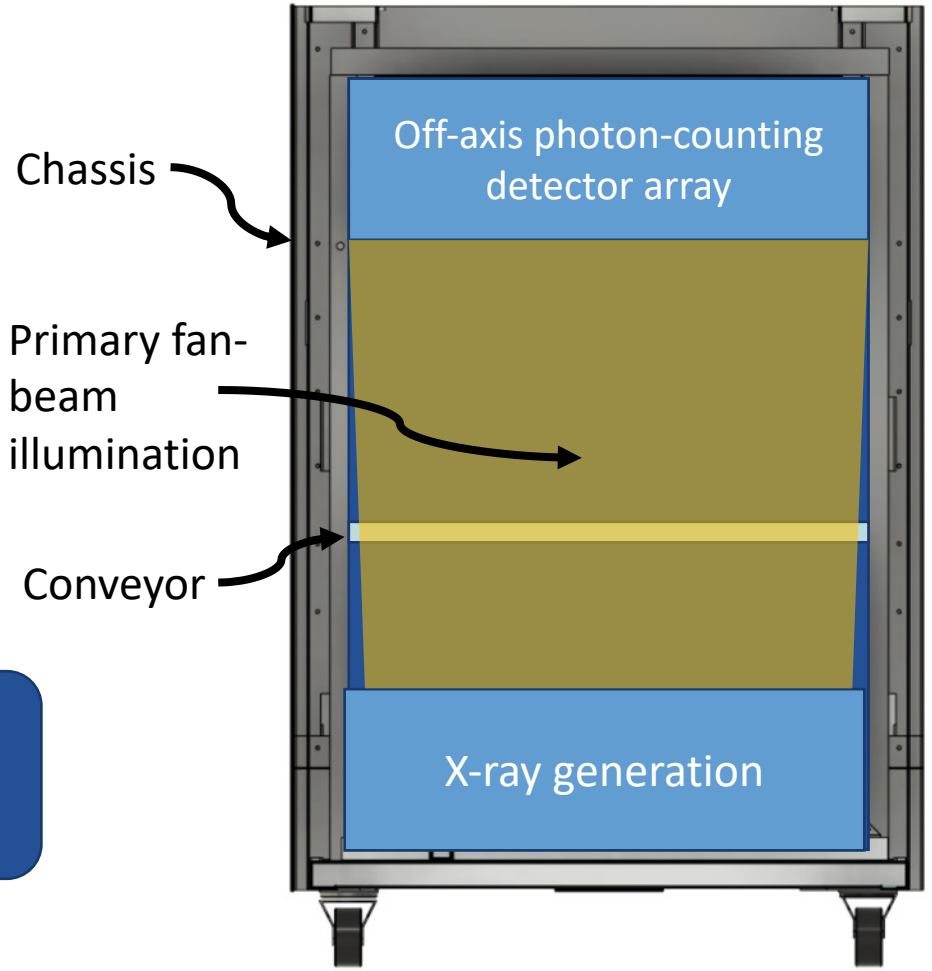
This work is supported by the U.S. Department of Homeland Security, Science and Technology Directorate, Explosives Division, (Contract number 70RSAT18CB0000044)

Checked baggage: high-level system description

XRD functional schematic



System implementation



X-ray imaging components are packaged such that the tunnel has coverage while the belt continues to move

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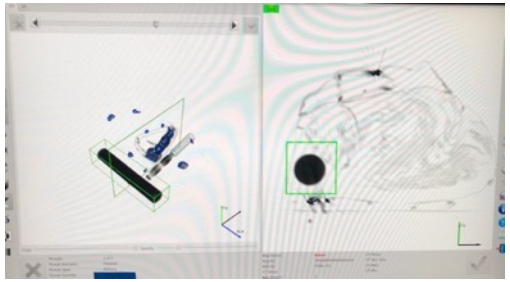
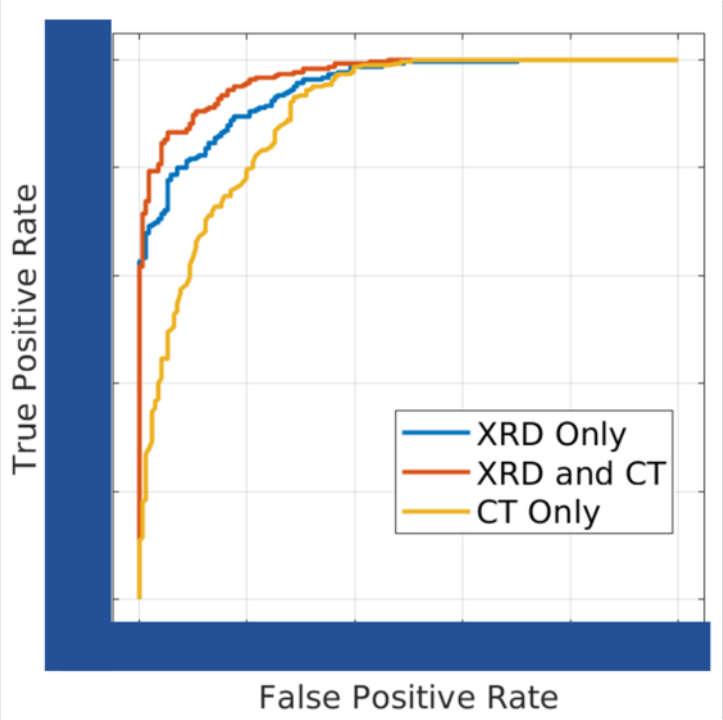
Checked baggage: detection results

Hybrid EP +CTX System Mechanically Integrated

Display using CTX visualization tools





- **Adding XRD information to CT results improves performance**
- **XRD and CT outperforms either XRD or CT alone**

  - CT Only – classify on alarmed objects using CT mean and std dev
  - XRD Only – classify on alarmed objects using mean form factor
  - XRD and CT – classify on alarmed objects using both sets of features

SVM on full 500+ bag dataset from QDX and TSL (trained with bare + some bags, no overlap between training and testing set)

*no certified algorithms were used in the calculation of these results

Coccarelli, David, et al. "Performance of a high-throughput full-tunnel XRD checked baggage scanning system." *Anomaly Detection and Imaging with X-Rays (ADIX) VIII*. Vol. 12531. SPIE, 2023.

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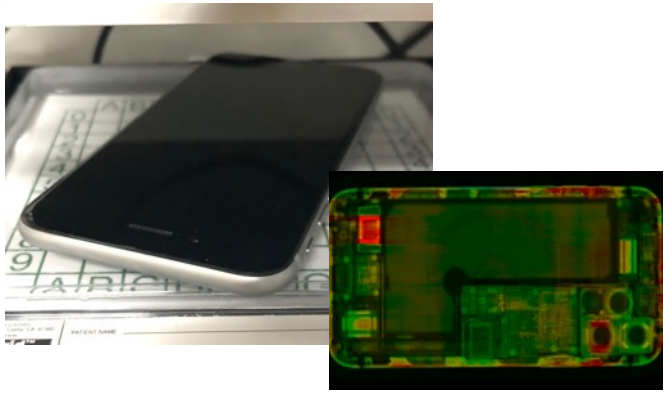
Tabletop XRD imaging + transmission

Quadridox's current system is designed for **analysis of small samples** (15 x 15 x 3 cm) providing **high-resolution transmission and X-ray diffraction imaging + automated detection**

Example applications

- Positive material ID
- Contraband inspection
- Agricultural
- Biological
- Explosives
- Electronics

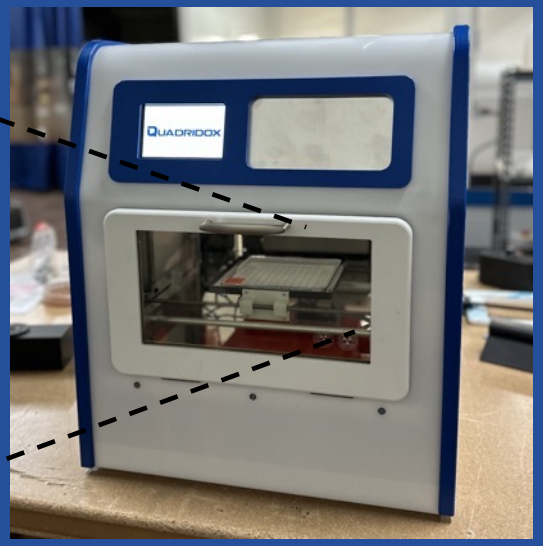
Electronics

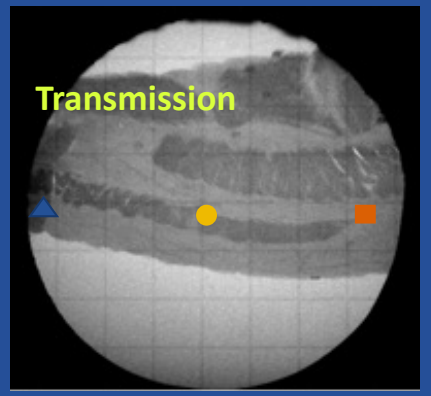


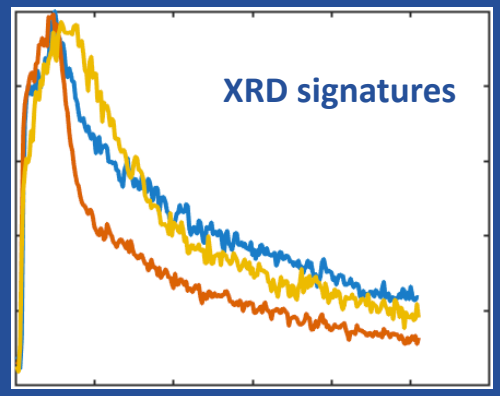
Candy/food/drugs

Quadridox XRD sample imaging system

Biological samples







Carpenter, Joshua H., et al. "X-ray diffraction texture: features for material identification (Conference Presentation)." *Anomaly Detection and Imaging with X-Rays (ADIX) V*. Vol. 11404. SPIE, 2020
Gude, Zachary, Anuj J. Kapadia, and Joel A. Greenberg. "3D x-ray diffraction imaging of optically thin samples." *Anomaly Detection and Imaging with X-Rays (ADIX) VII*. Vol. 12104. SPIE, 2022.
Greenberg, Joel A., et al. "Concealed drug detection via fan beam coded-aperture x-ray diffraction imaging." *Anomaly Detection and Imaging with X-Rays (ADIX) VI*. Vol. 11738. SPIE, 2021.

This work is not funded through DHS

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Questions?

X-ray diffraction (XRD) imaging

Better patient care

Safe and easy travel

Optimal process control

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https://www.quadridox.com

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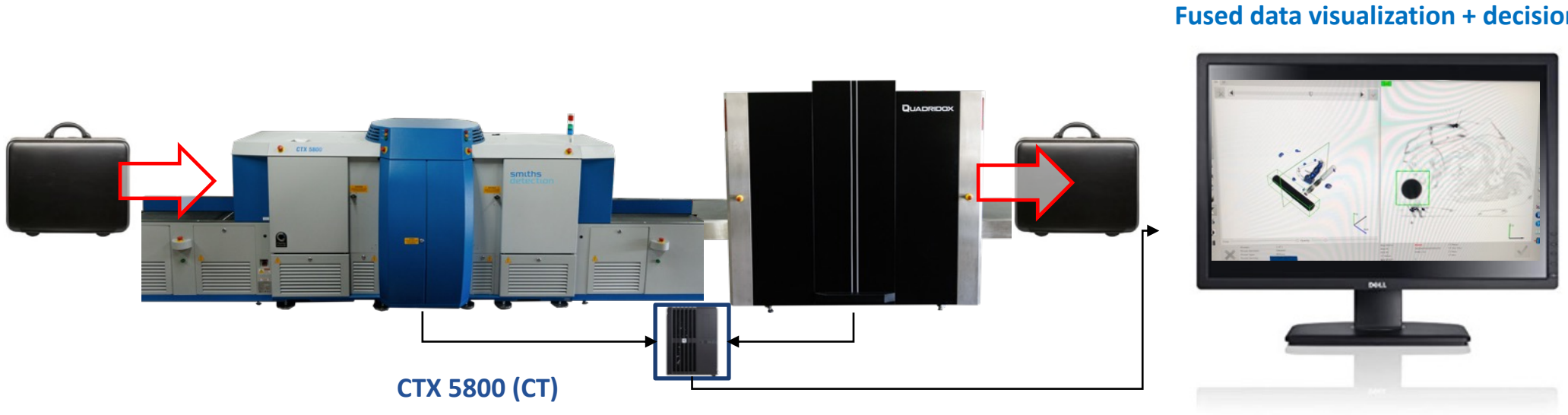
Backups

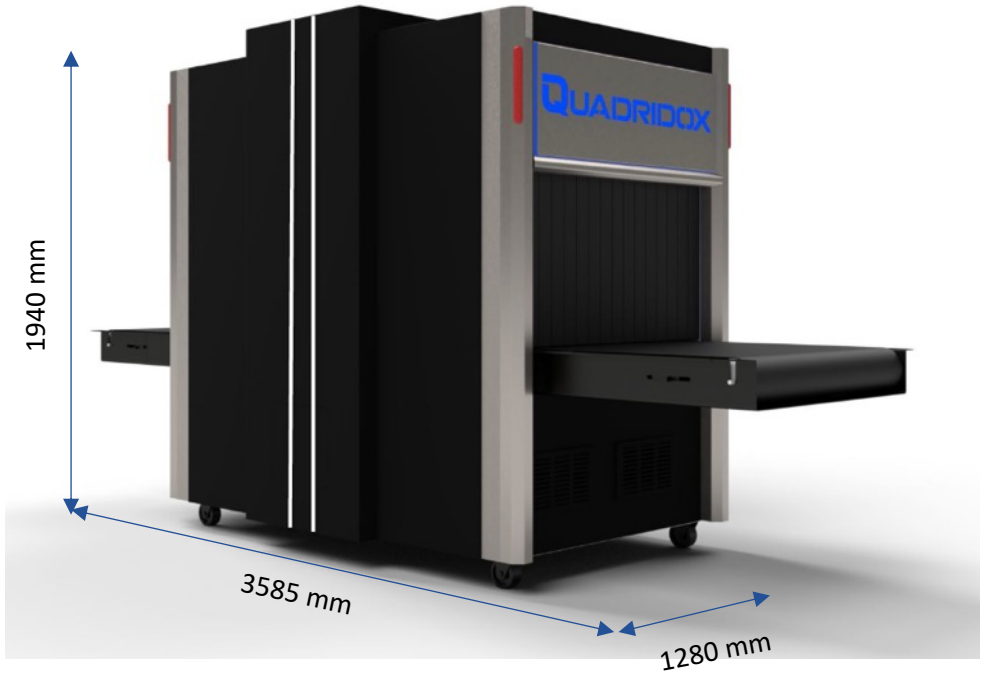
Hybrid system concept

- **Hybrid system concept:** combine strengths of transmission and diffraction systems to fill the capability gaps of each system and realize improved system performance
  - Hybrid system involves a fully-integrated XRD design with a single, joint decision
  - Requires real-time scanning
- Integration implementation
  - **Modular, vendor-agnostic design (this project)**



Quadridox XRDI Engineering Prototype

The Engineering Prototype (EP) is **Quadridox's** modular, vendor-agnostic system that can **resolve alarms anywhere in the tunnel at native EDS speeds**



CAD rendering of EP

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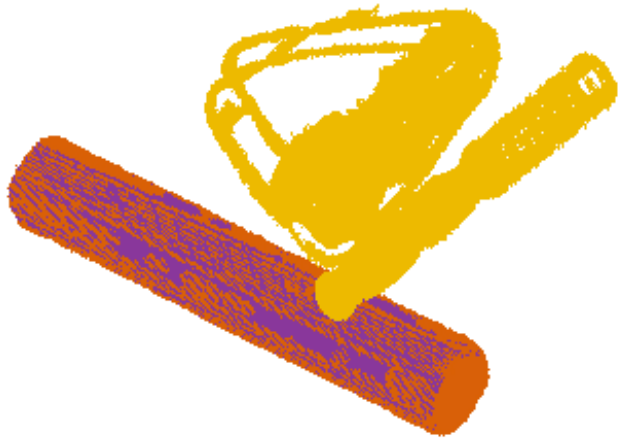
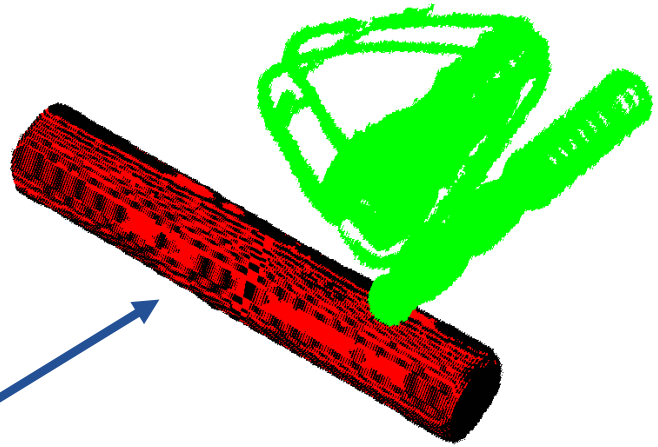
Hybrid data: CTX 5800 output

CT density volume

CT segmentation masks



CT alarm decisions



Main goal: confirm or clear alarms