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Materials Discrimination for Air Cargo

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What Benefit Can TSA Gain?

TSA already uses materials discrimination technology – the focus of this talk

The issue is how best to optimize systems for Air Cargo inspection which suffer from

- Large Tunnel Size
- Complex Cargo Contents

Here we discuss the effect of changing X-ray beam quality on the ability to categorize explosive materials

Explosives Detection in Air Cargo with X-ray Systems: The Challenge

Tunnel Size

Large tunnel sizes mean that we need higher energies to penetrate cargo.

This means that Z-effective resolution tends to drop which impacts ability to discriminate explosive materials

Image Complexity

Contents of air cargo is much more diverse than cabin baggage

This makes inspection of images much more difficult than standard cabin baggage style image inspection

Explosives Detection in Air Cargo with X-ray Systems: The Challenge

Penetration

High density air cargo requires high energy system to achieve penetration performance:

- 160kV – 40mm
- 300kV – 60mm
- 1MV – 120mm
- 6MV – 400mm

The higher the energy, the less the ability to categorize explosives reliably

Spatial Resolution

High complexity cargo requires images of excellent resolution to achieve good diagnostic quality

Higher energy systems tend to have lower spatial resolution due to physics reasons including:

- power density on X-ray target
- longer range of Compton recoil electrons in the detector

Explosives Detection in Air Cargo with X-ray Systems: The Challenge

Overlapping Structures

In principle, we can get rid of overlapping structures (which affect Z-effective) by going to CT style imaging

This gets very expensive since you still need to use high energy sources to meet penetration requirements and reduce streak artefact

In principle with voxel based density and Z-effective, explosives categorization can be good

Anomaly Detection

By use of anomaly detection, it may be possible to see threat materials

- Multiple objects in one consolidated cargo are identical except that one is slightly different
- Comparison of image to manifest (e.g. expect three boxes but see four)

Summary

This is a difficult problem whose complexity should not be underestimated

Large tunnels really need high energy inspection beams to achieve penetration requirements but this severely compromises ability to categorize materials into specific types

Once an image is formed, it is then difficult to analyze due to clutter and overlapping structures

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Backup

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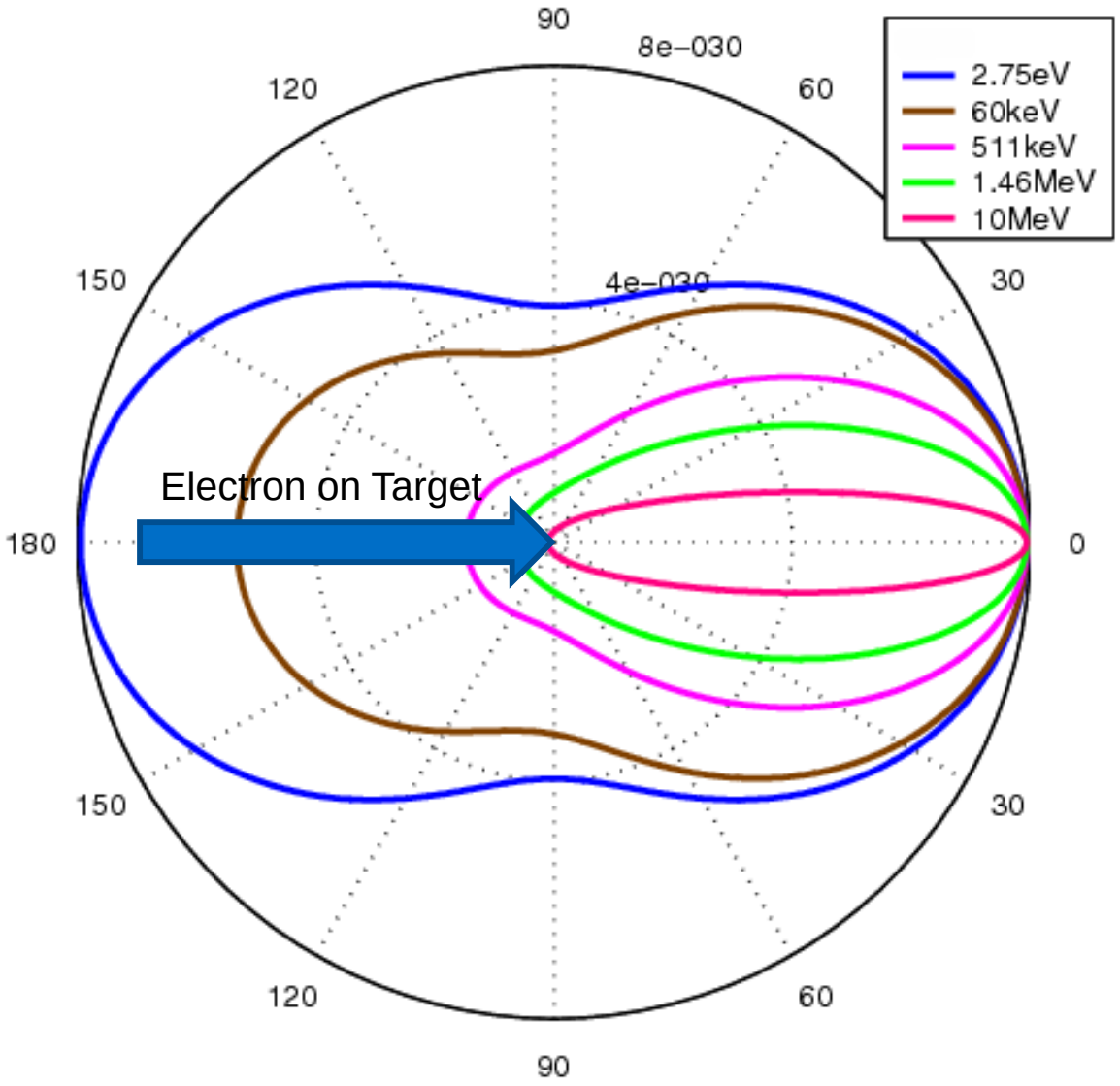
Basic Physics

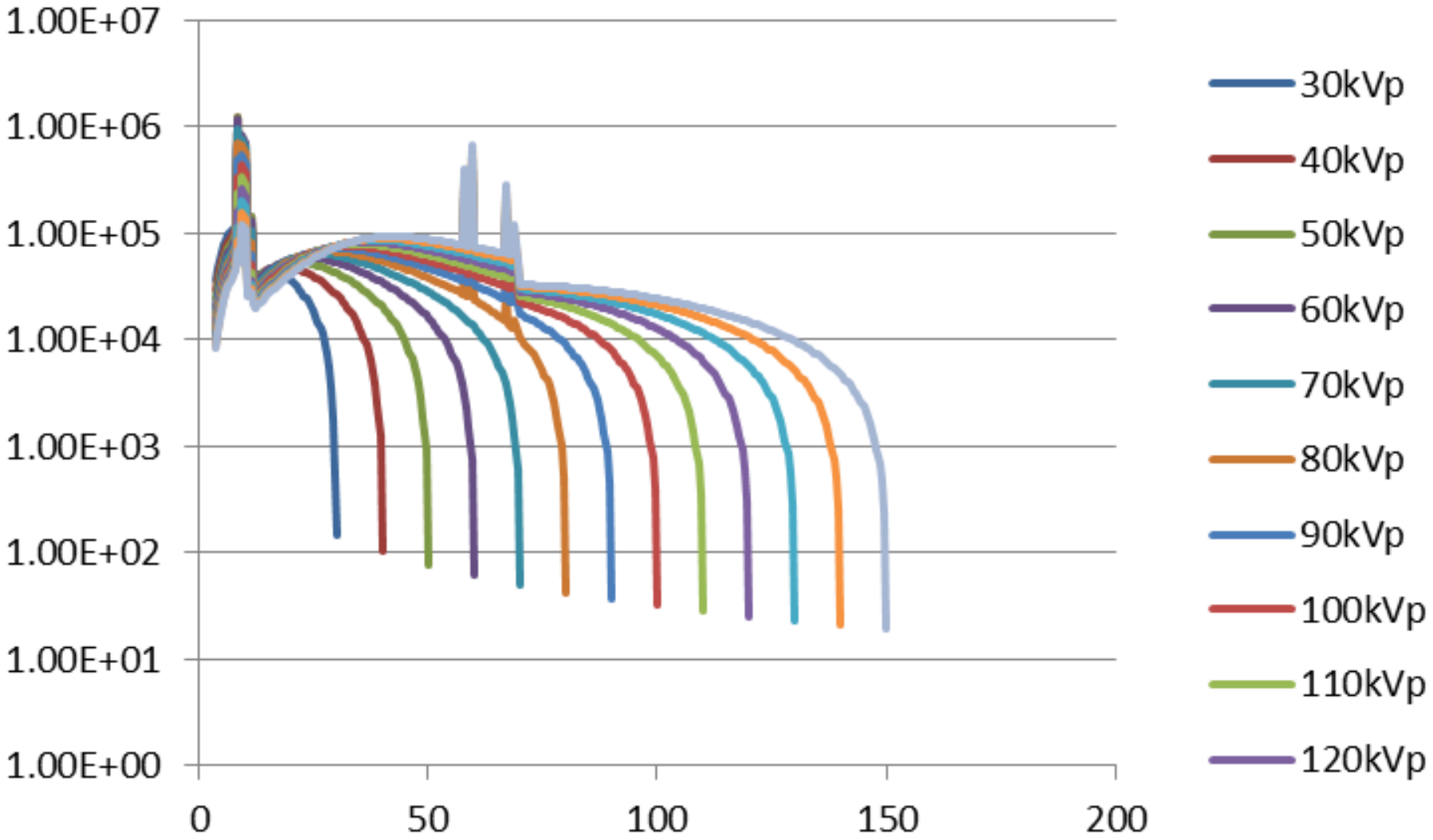
X-Ray Generation



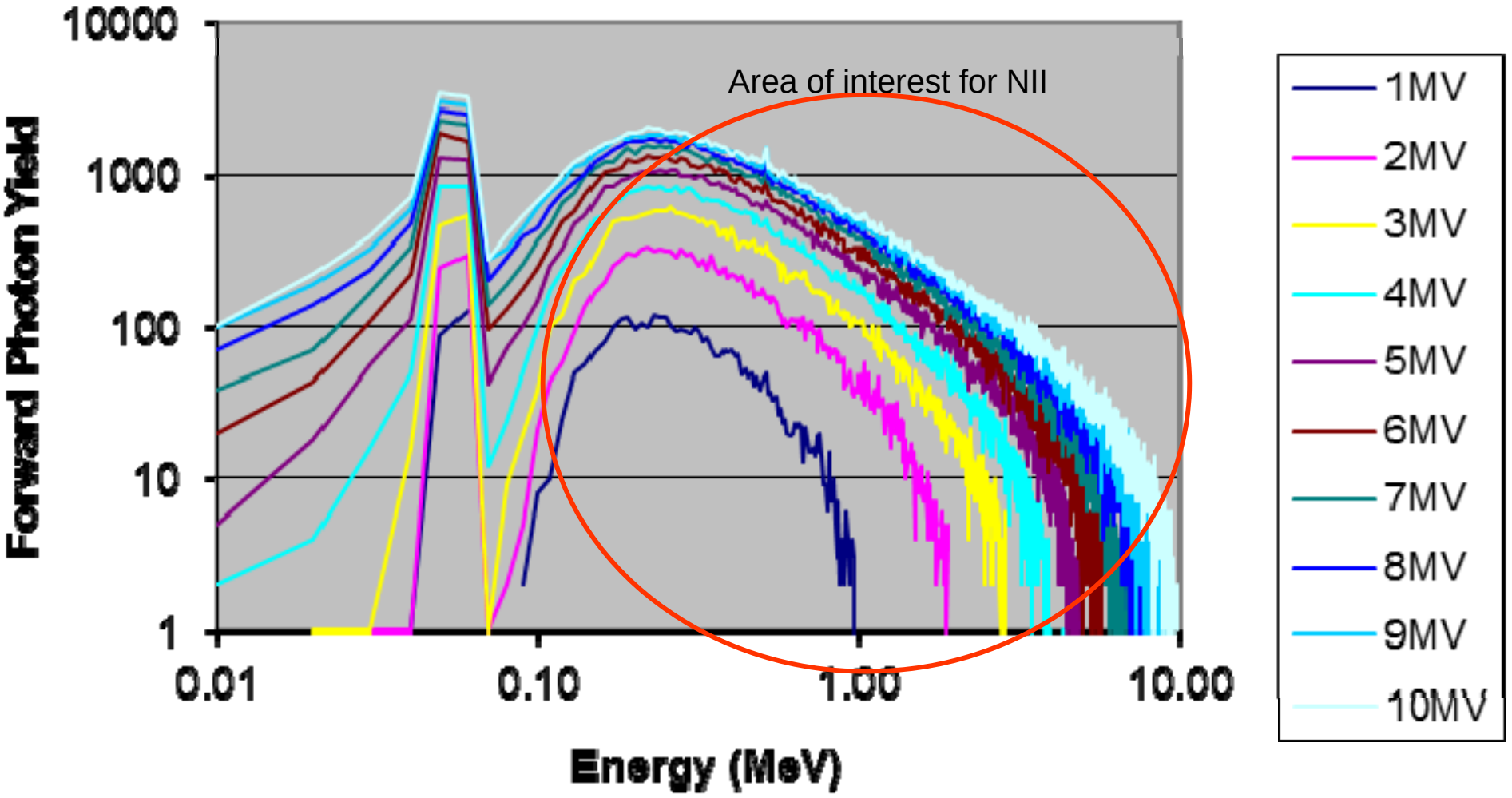
At low energies, X-ray production is almost isotropic

At high energies, X-ray production is much more forward directed

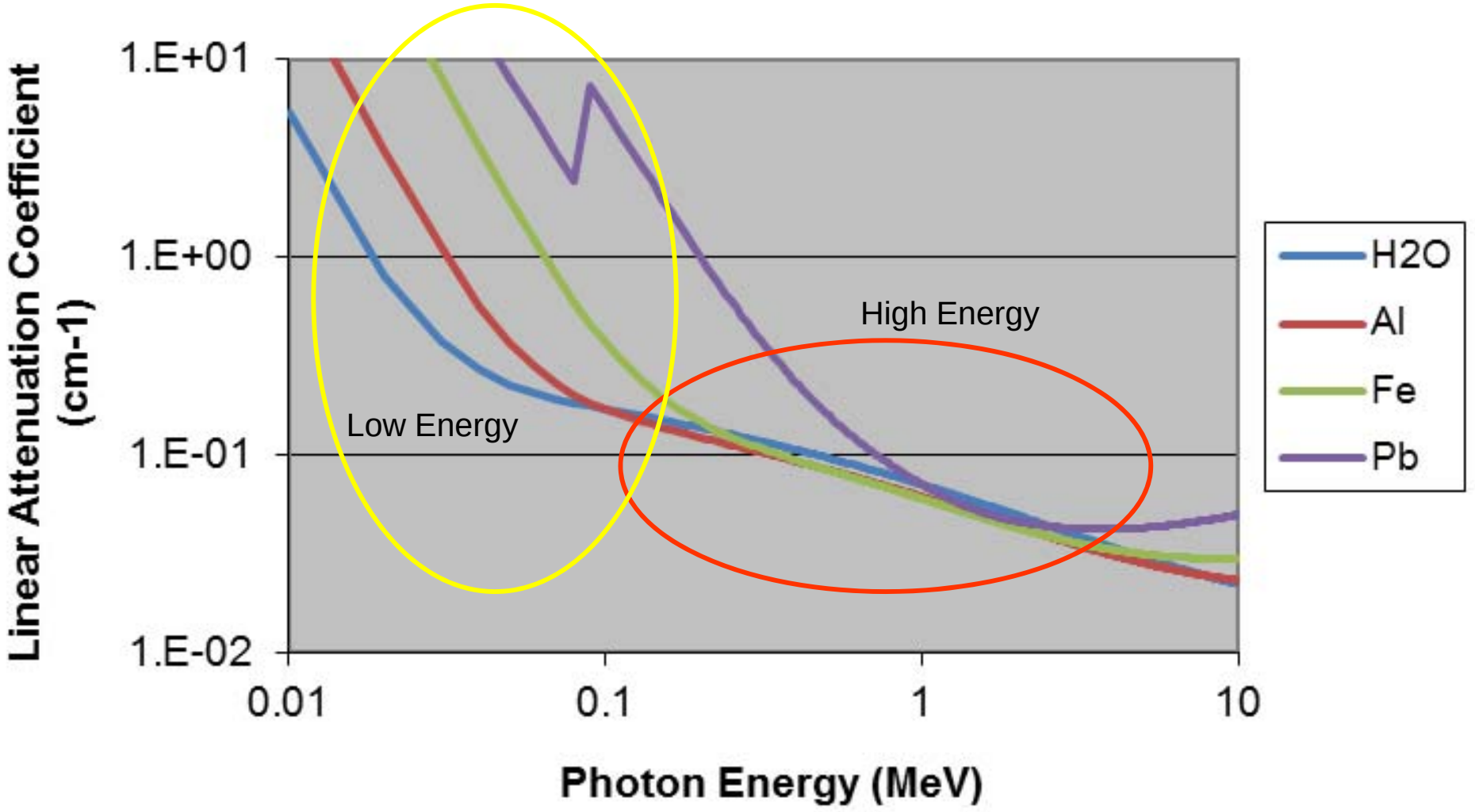
X-Ray Spectra – Low Energy



X-Ray Spectra – High Energy



Material Attenuation



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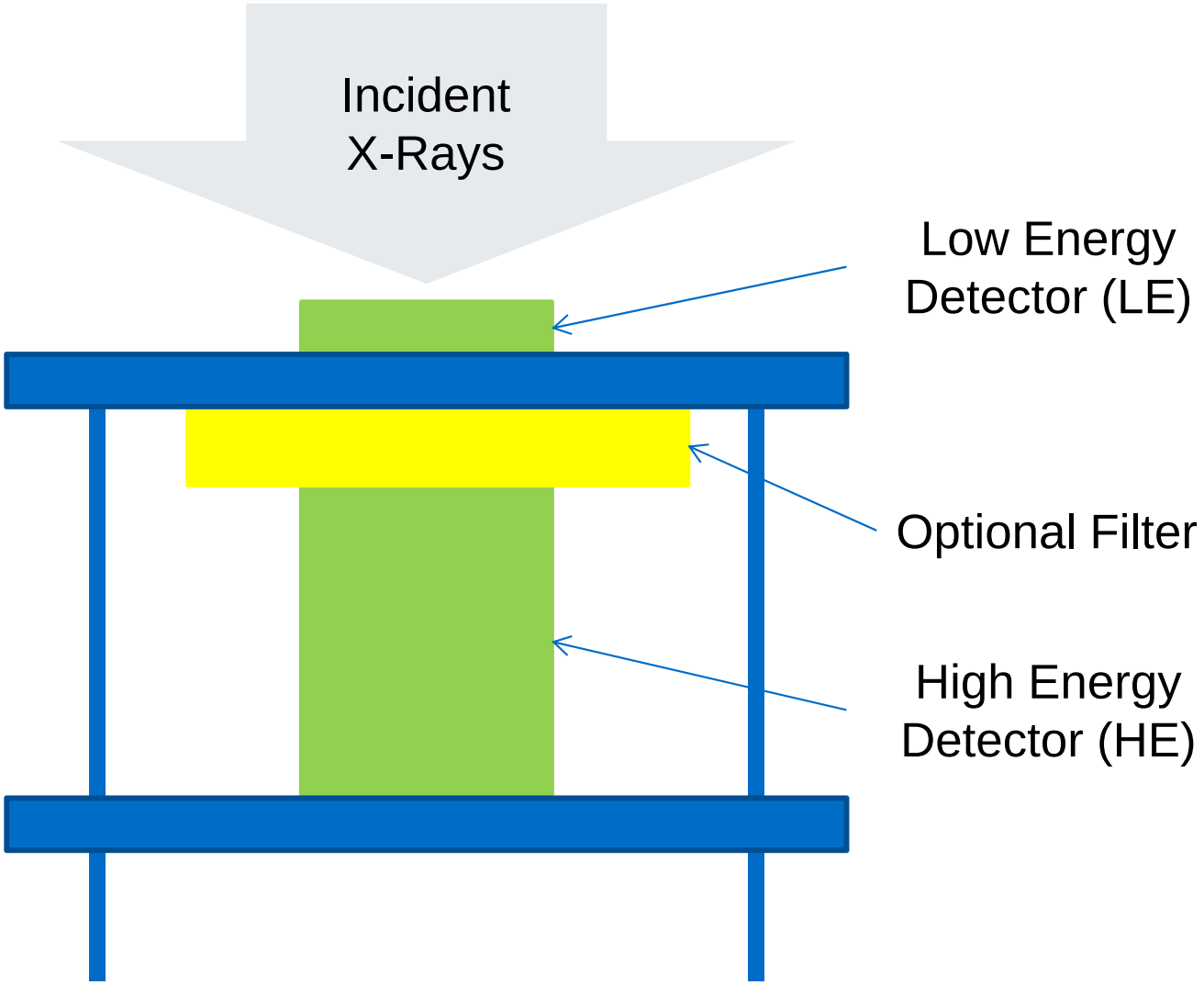
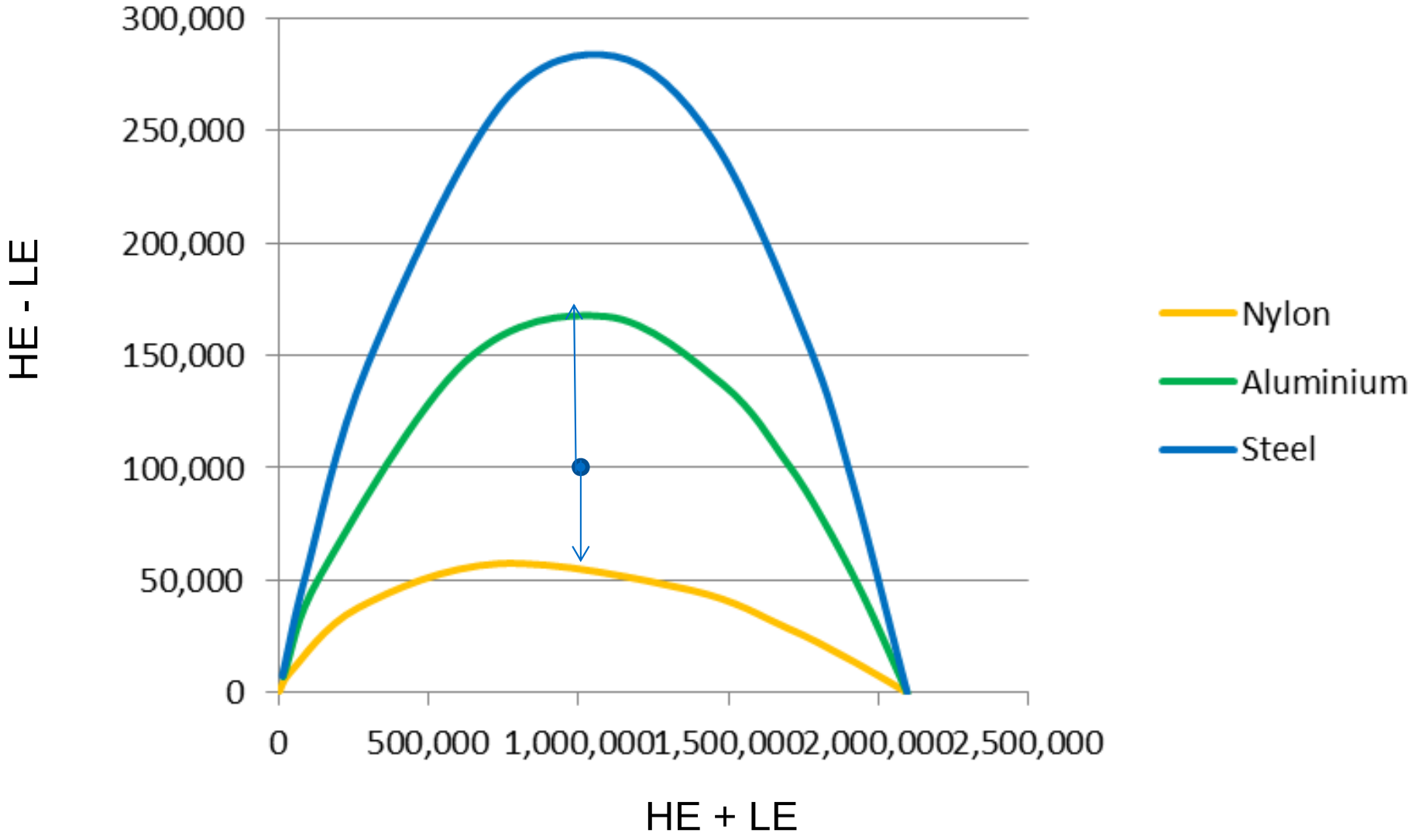
Materials Discrimination
Low Energy (Small Tunnel)

Dual Energy Detection



Dual Energy Materials Discrimination



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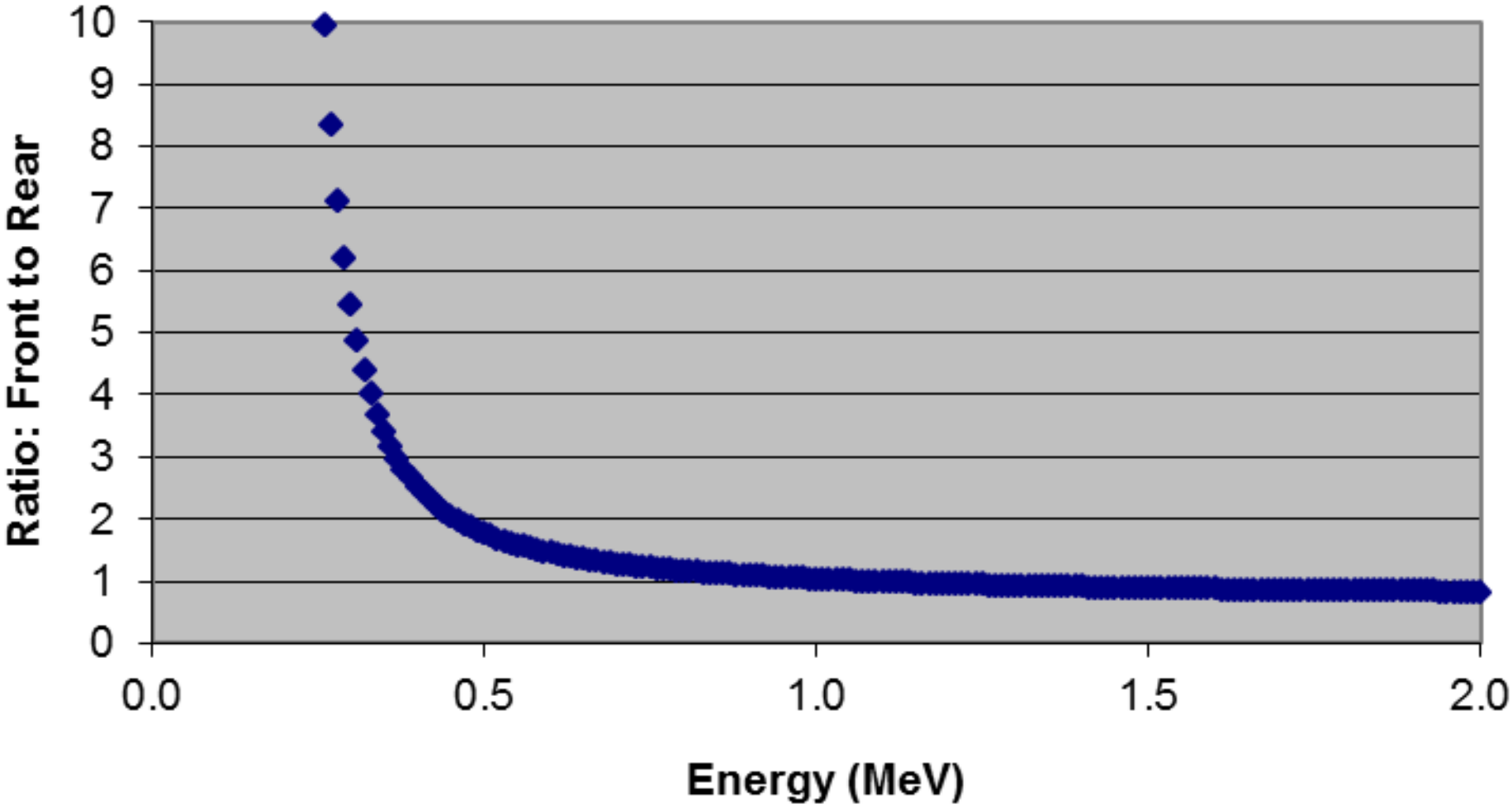
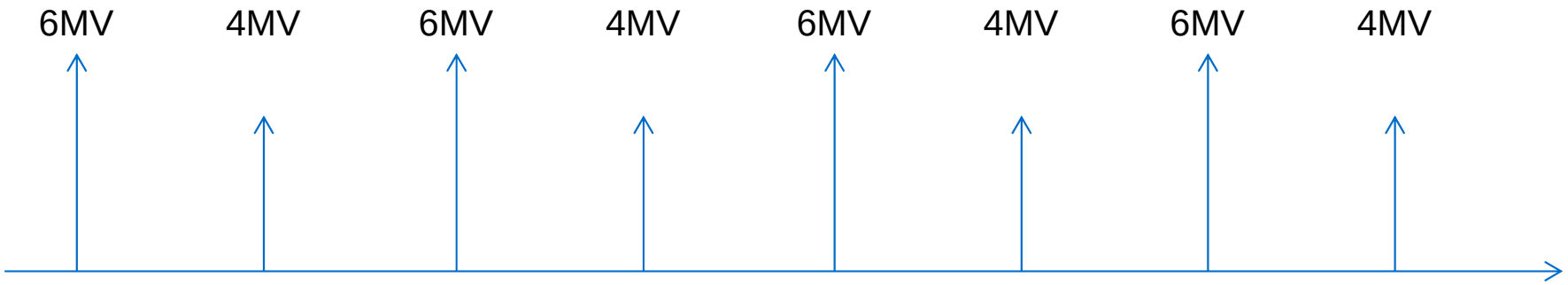
Materials Discrimination
High Energy (Large Tunnel)

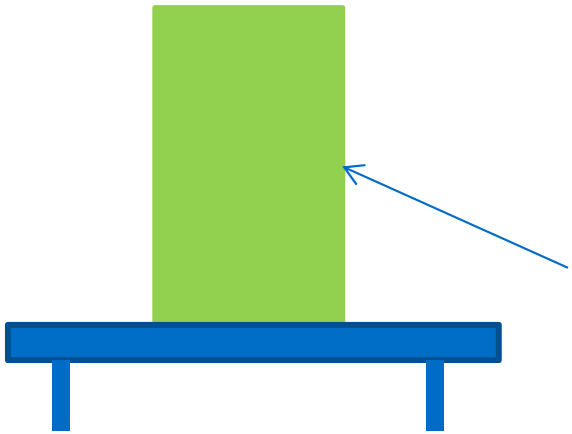
Dual Energy Detection at High Energy



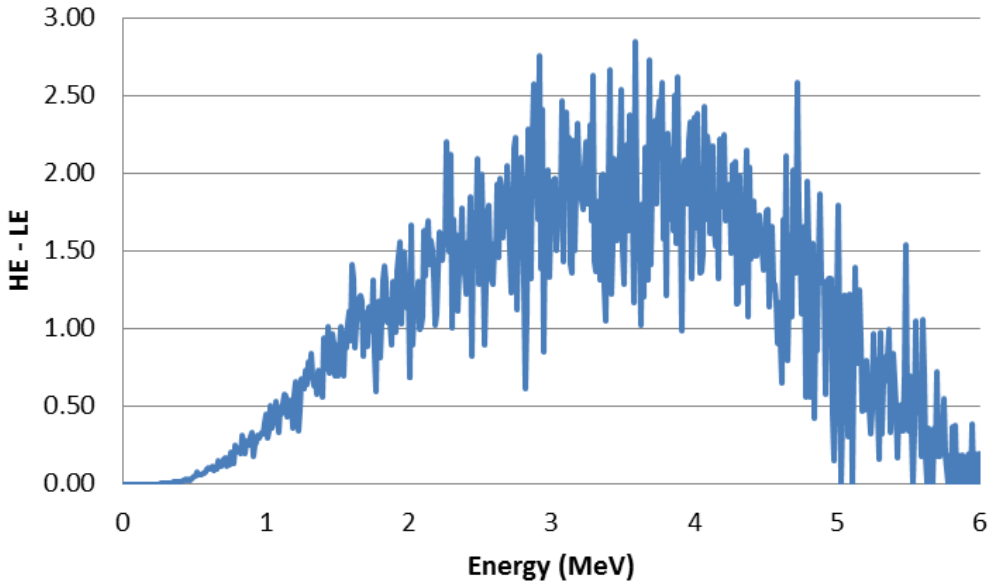
Dual Energy Imaging at High Energy

Interlaced Energy Beams from a Linear Accelerator X-Ray Source

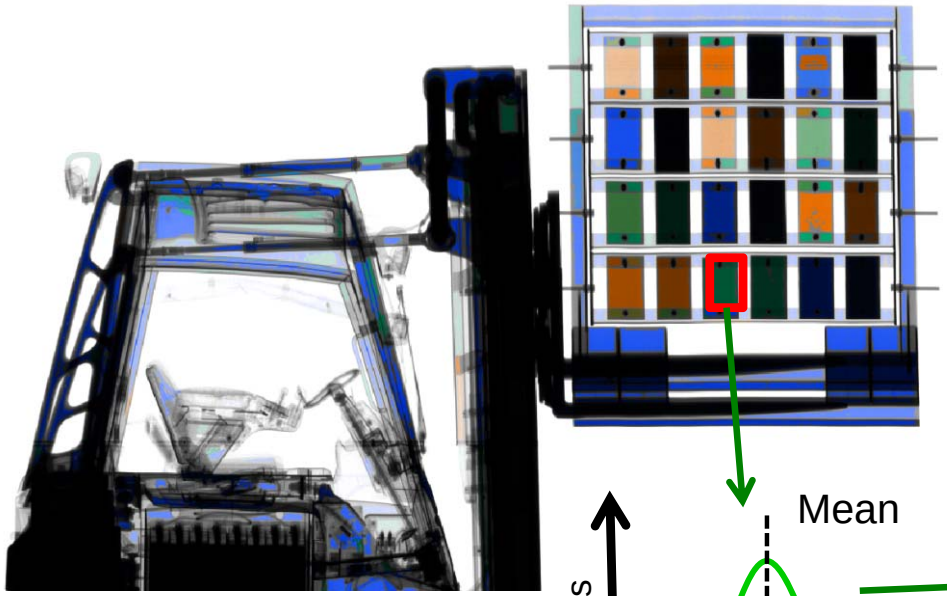


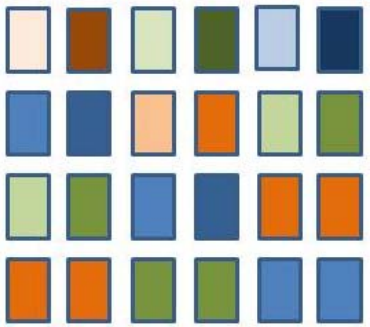


Single Energy Detector

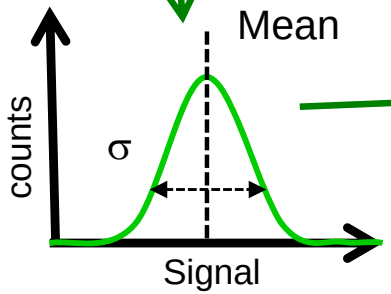


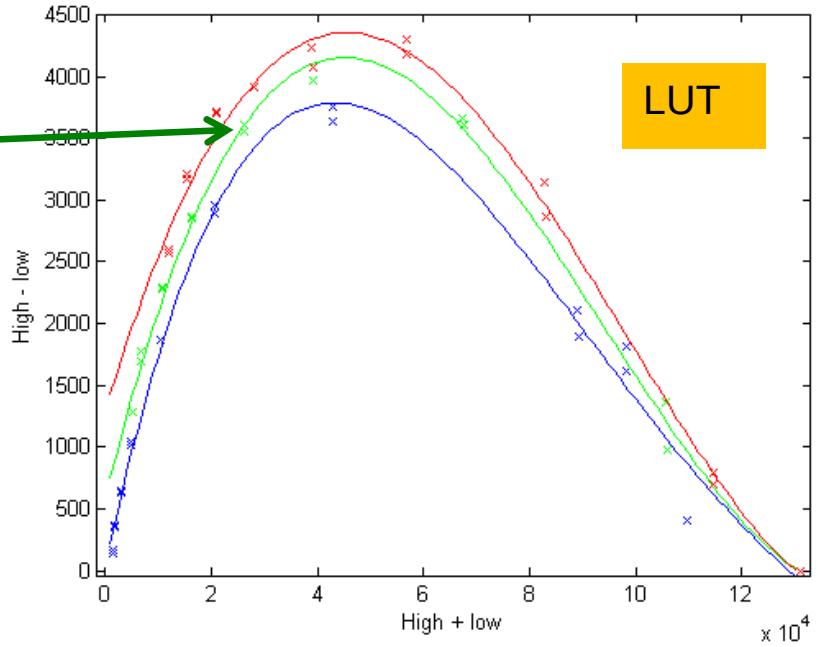
Dual Energy Imaging



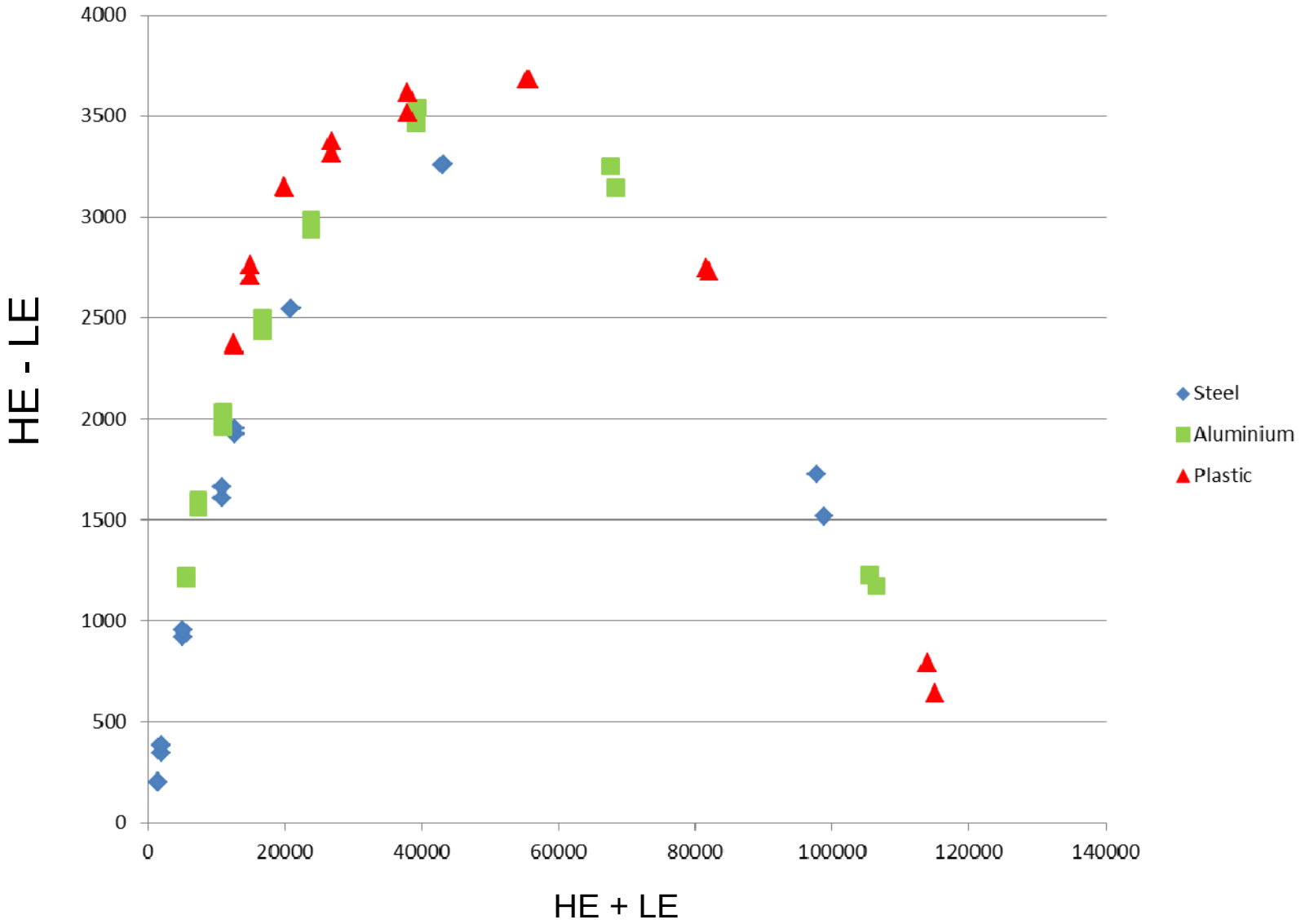


Orange = Plastic
Green = Aluminium
Blue = Steel



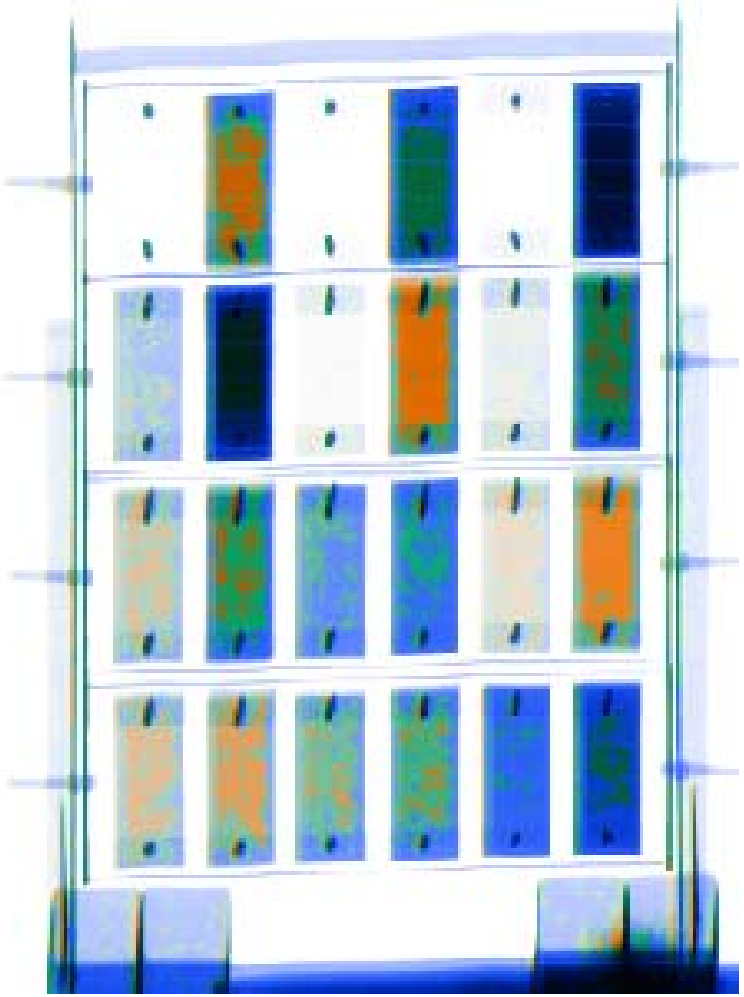


Dual Energy Imaging

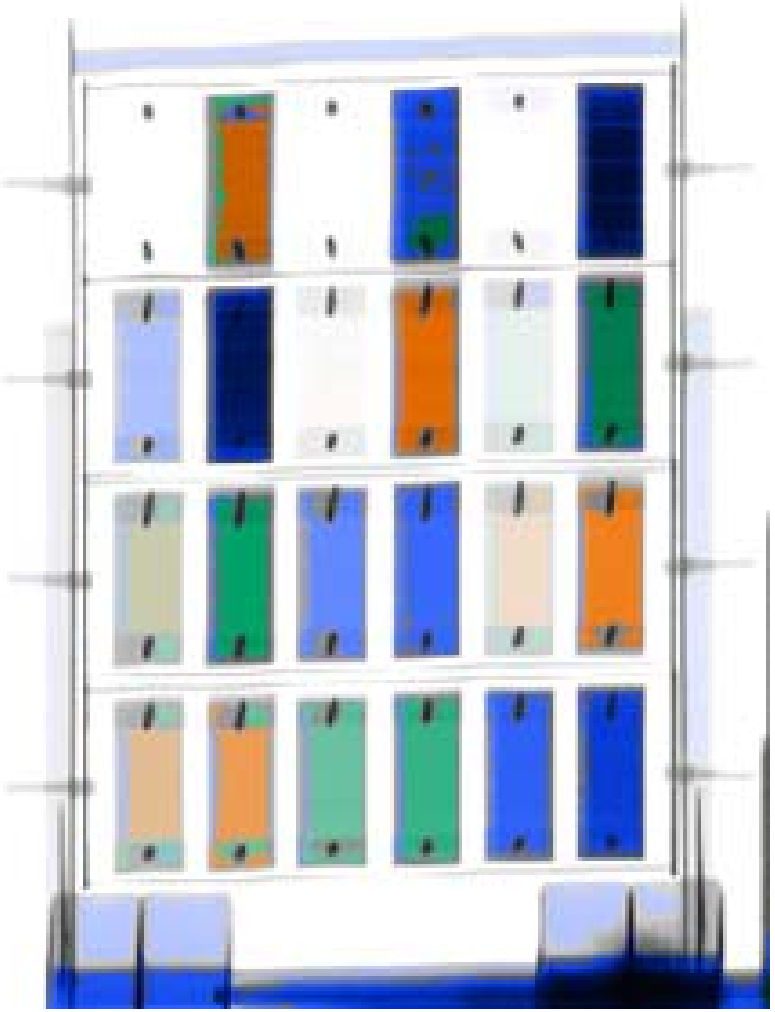


Dual Energy Imaging

Raw Data



Smoothed Data



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