M.4 Radiographic Testing

Eliminating Artifacts and Boosting Efficiency with Varex TrueSpectrum™ Imaging

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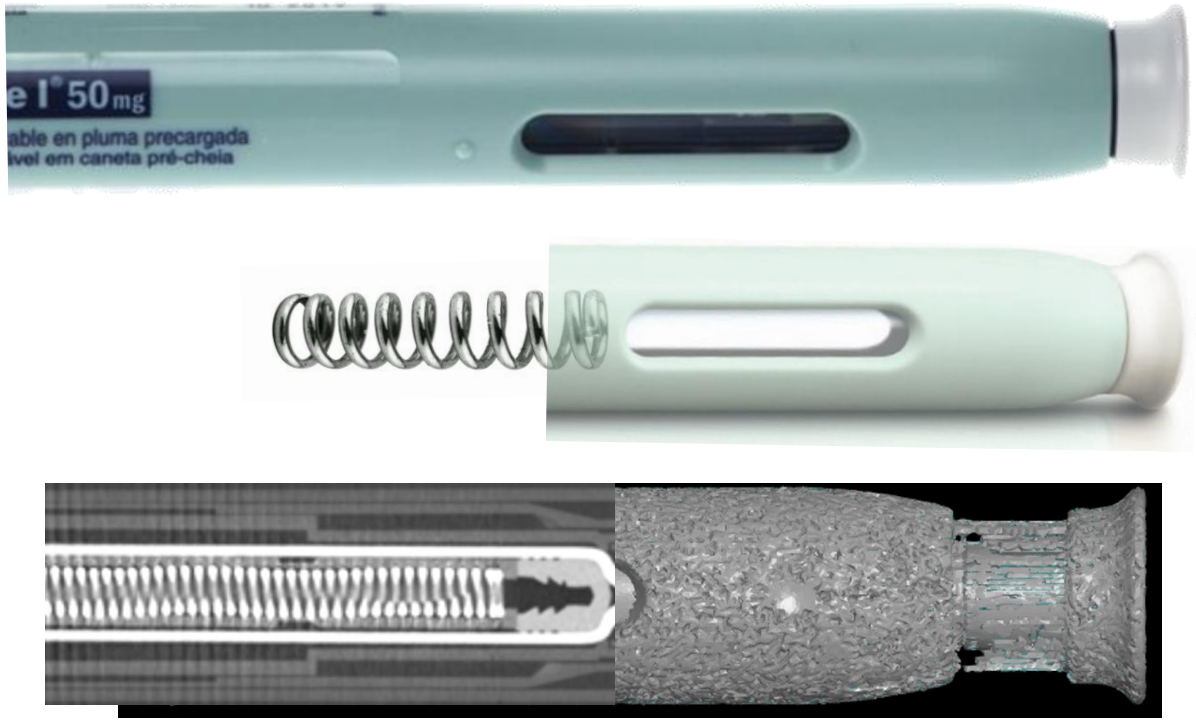
Varex Imaging AG, Walluf, Germany

The Core Challenge: Avoiding CT Artifacts

Artifacts Prevent Detection -- Artifacts Prevent Measurement



Metal + Plastic = Artifacts

→ **Artifacts lead to poor image quality**

→ **We can't inspect what we can't see**

→ **We can't measure what's buried in noise**

The Core Challenge: Avoiding CT Artifacts

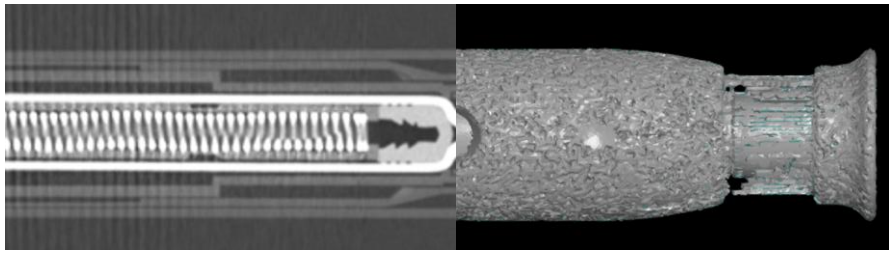
Where do artifacts come from?

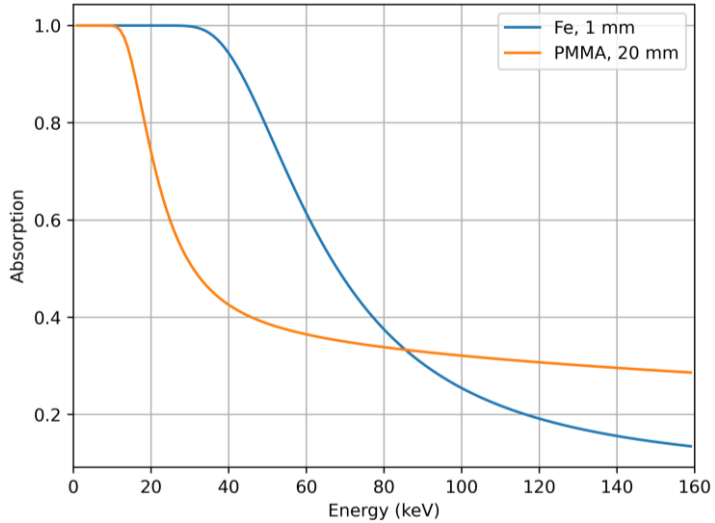
CT reconstruction math: assumes monoenergetic X-rays — polychromatic sources violate this assumption

$$I_x = I_0 * e^{-\mu x}$$

$$I_x = I_0 * e^{-\int_0^{Emax} \mu(E) x dE}$$

Multi-material objects (metal + polymer) make the problem worse: highly nonlinear beam absorption





Test Object: Pharmaceutical Injection Pen

An industry-relevant multi-material challenge

Off-the-shelf auto-injector pen — real-world inspection scenario

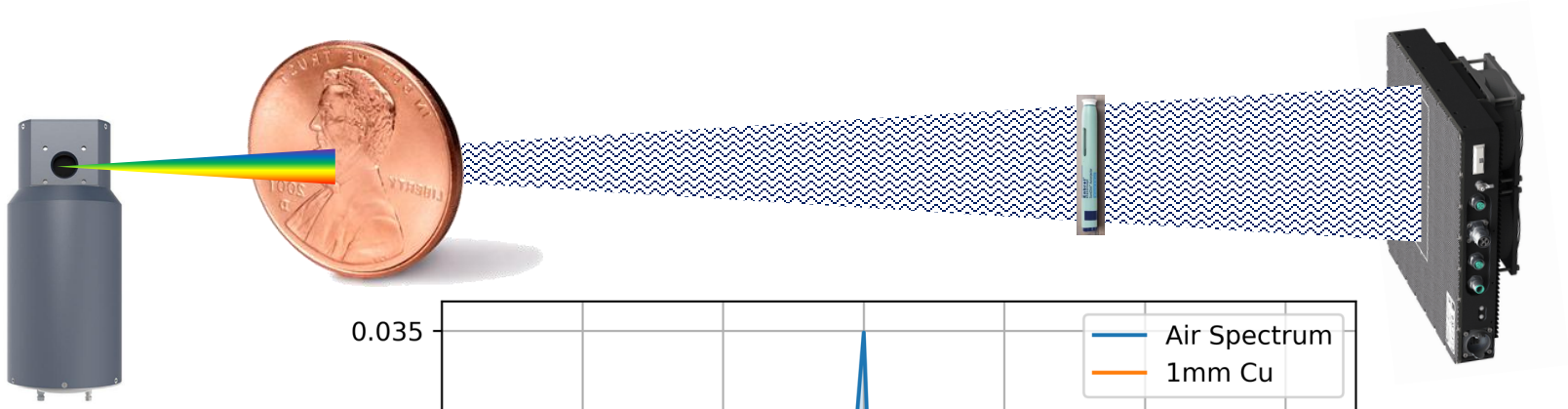
Multi-material composition:
→ Polymer housing + Steel

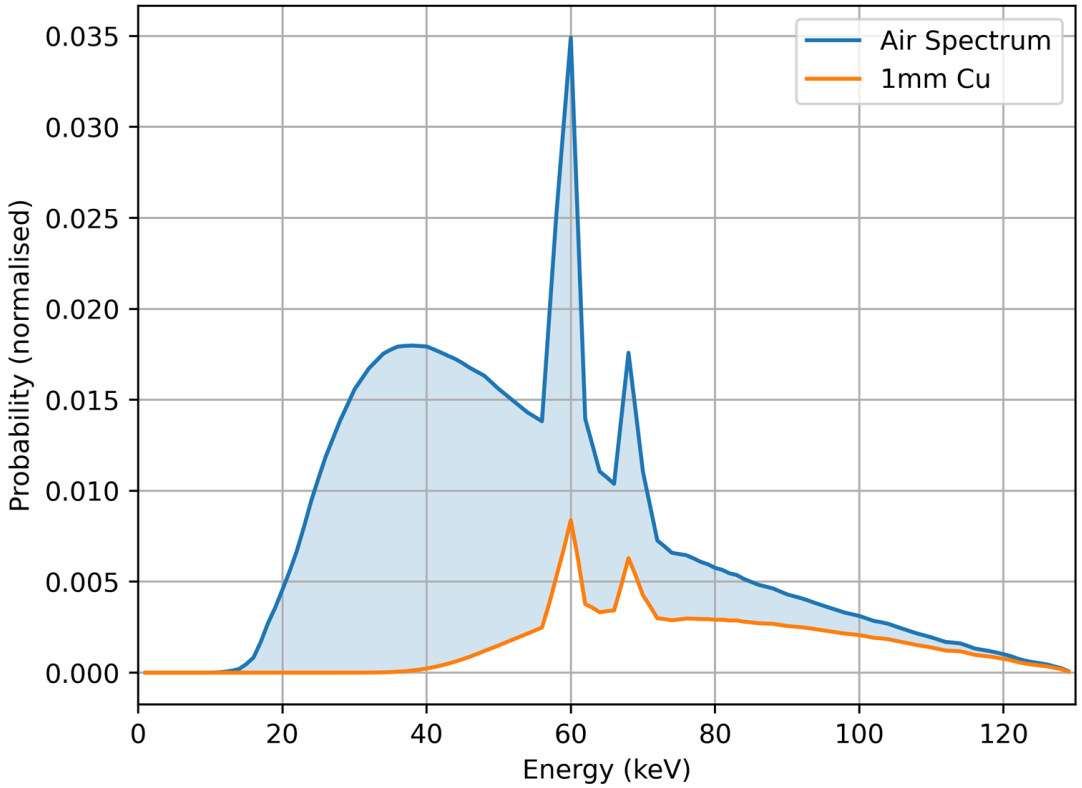
Why it is **challenging**:
→ Artifacts from huge absorption difference in materials

What we **want to see**:
→ Clean outside plastic surface
→ Reduction of artifacts inside and outside the steel spring

The Conventional Answer: Heavy Beam Filtration

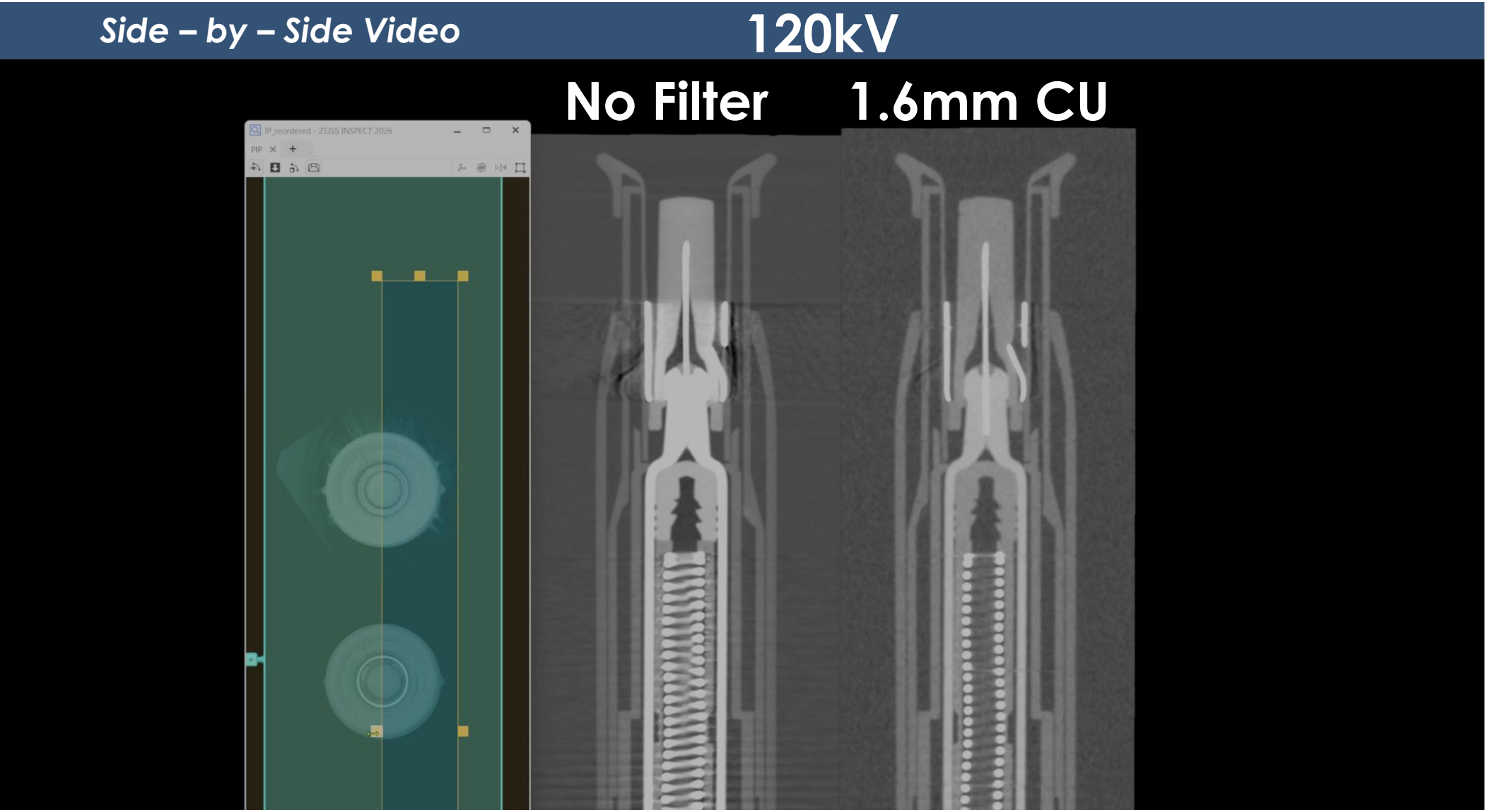
Physical filters reduce artifacts successfully — but at a cost





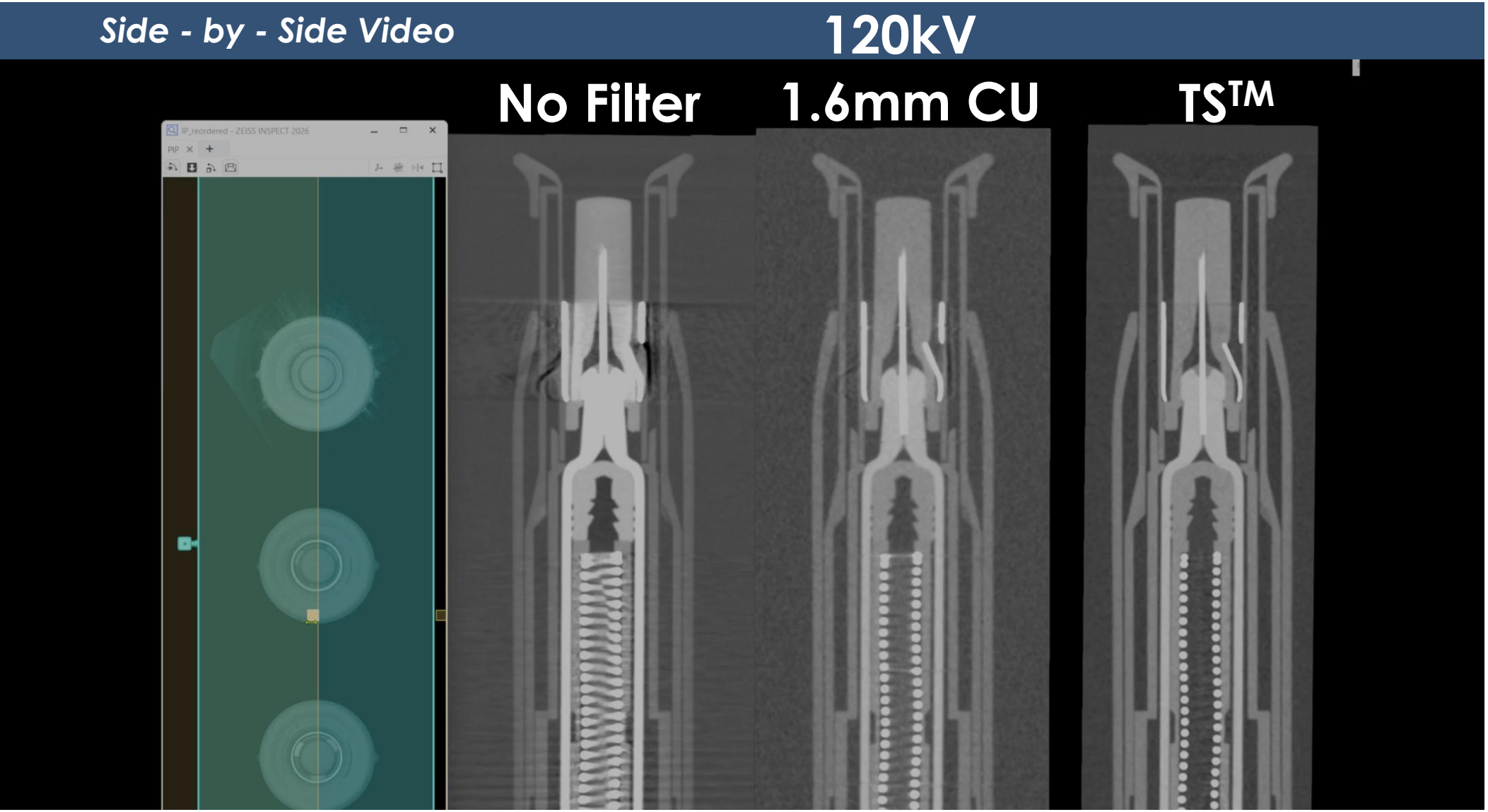
The Conventional Answer: Heavy Beam Filtration

Side – by – Side Video



The Varex Answer: TrueSpectrum Imaging

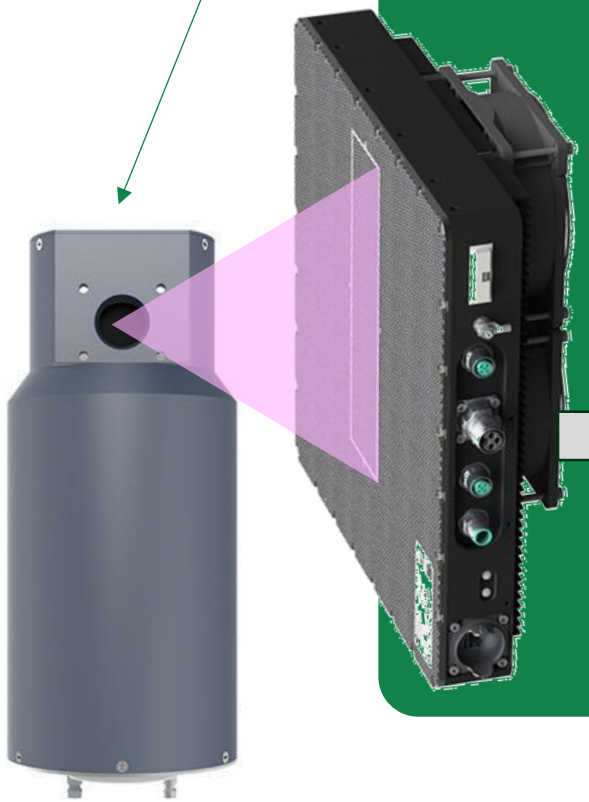
Side - by - Side Video



The Varex Answer: TrueSpectrum™ Imaging

Help users access the full spectrum

NO FILTER



TrueSpectrum

RECIPES

ACQUISITION HOW-TO's

CALIBRATION

MATERIAL DE-COMPOSITION

VMI

TSX (TrueSpectrumExpress)

CT RECONSTRUCTION

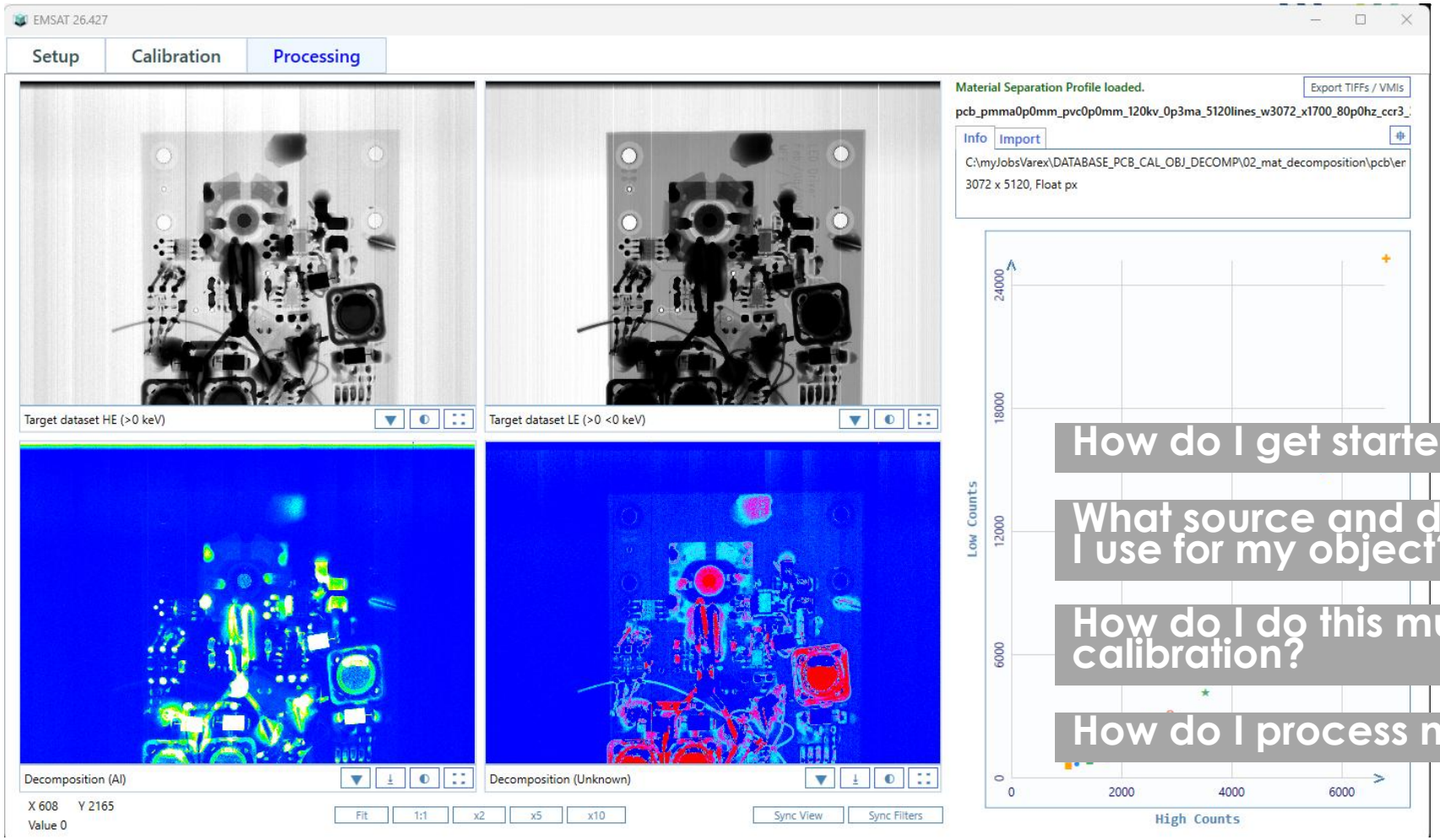
DIRECT 2D ANALYSIS

THOR

TrueSpectrum™: making dual energy accessible

Focus on helping user navigate: Recipes, Material Separation, VMI output

RECIPES **ACQUISITION HOW-TOs** **MATERIAL SEPARATION** **VMI GENERATION**



How do I get started?

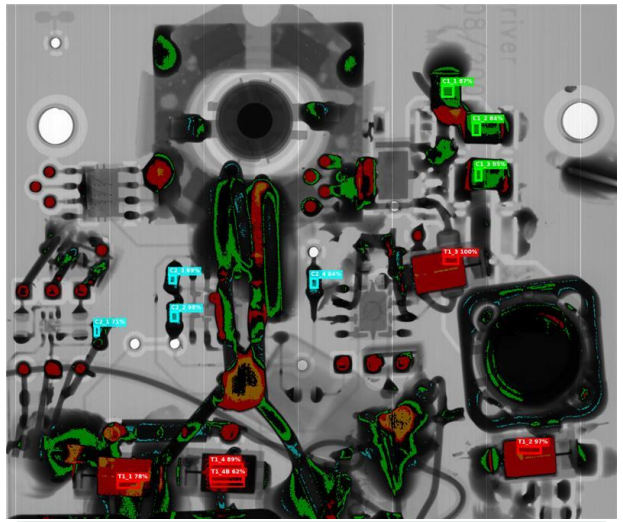
What source and detector settings should I use for my object?

How do I do this multi material calibration?

How do I process my images?

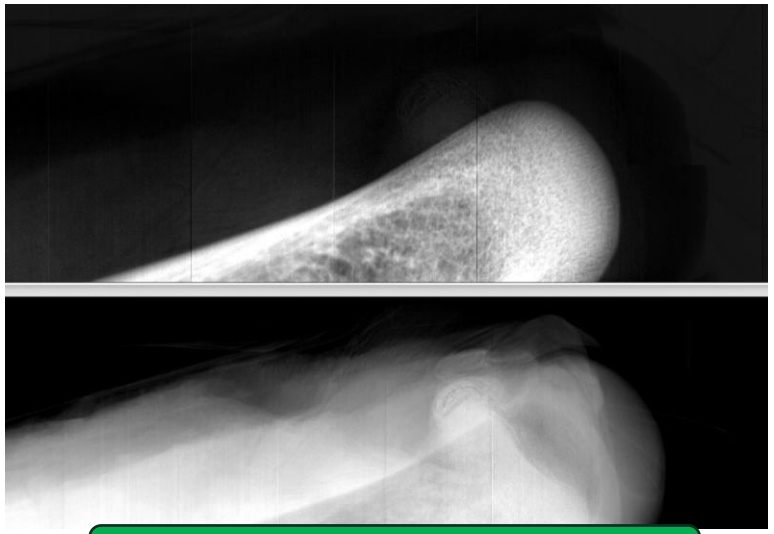
TrueSpectrum™: making dual energy accessible

Many possibilities: 2D, IQ improvement, Material Separation



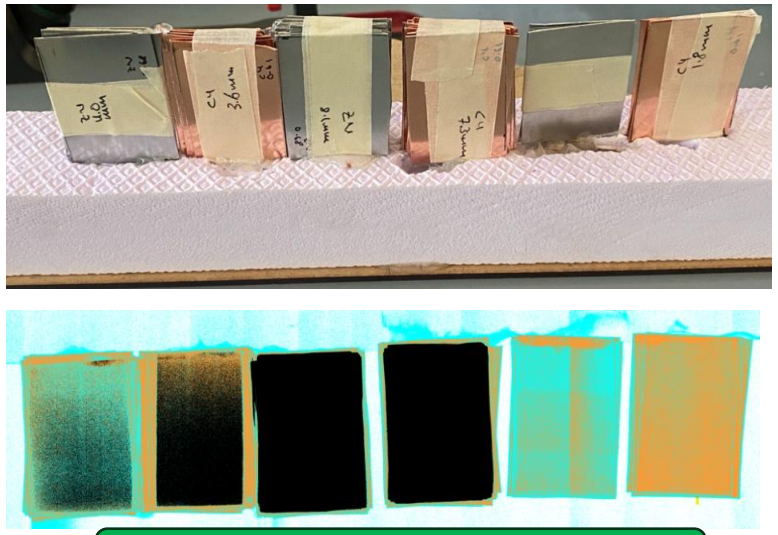
2D: Identify Different Parts with similar density

Ceramic Capacitors



2D: Separate Materials with similar density

Chicken Wing



2D: Separate Materials with similar density

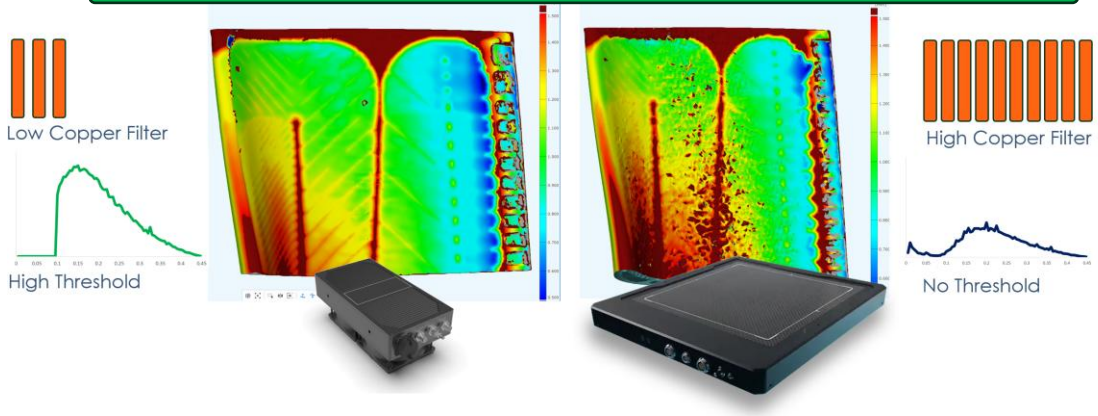
Copper vs Brass

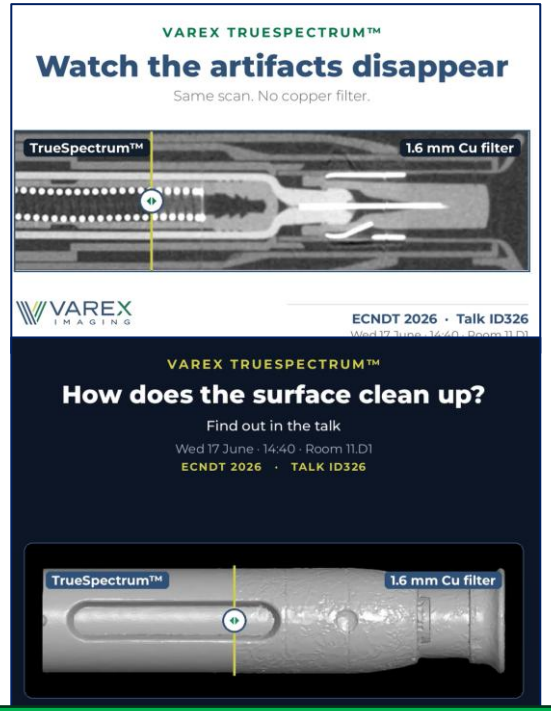
TrueSpectrum™: making dual energy accessible

Many possibilities: 3D

Turbine Blade CT

Scatter Control using Thresholding





VMI + TSx

Injection Pen

Creating a Recipe

Exploring the solution space of the pen – with TrueSpectrum

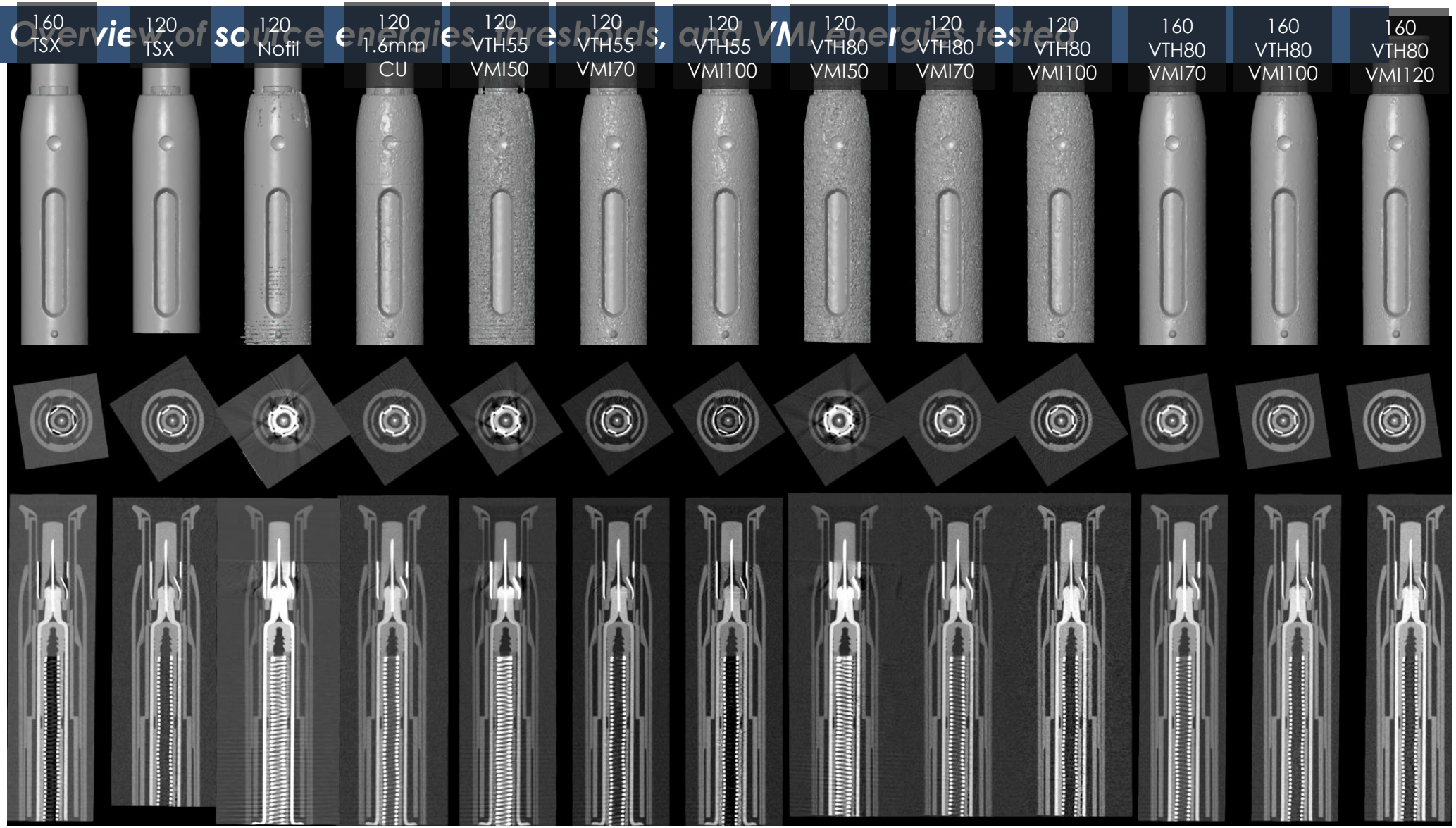
Back to the pen.

Lets do some heavy lifting.

So you don't have to later!

All Dual-Energy Settings Tested

Overview of source energies, thresholds, and VMI energies tested



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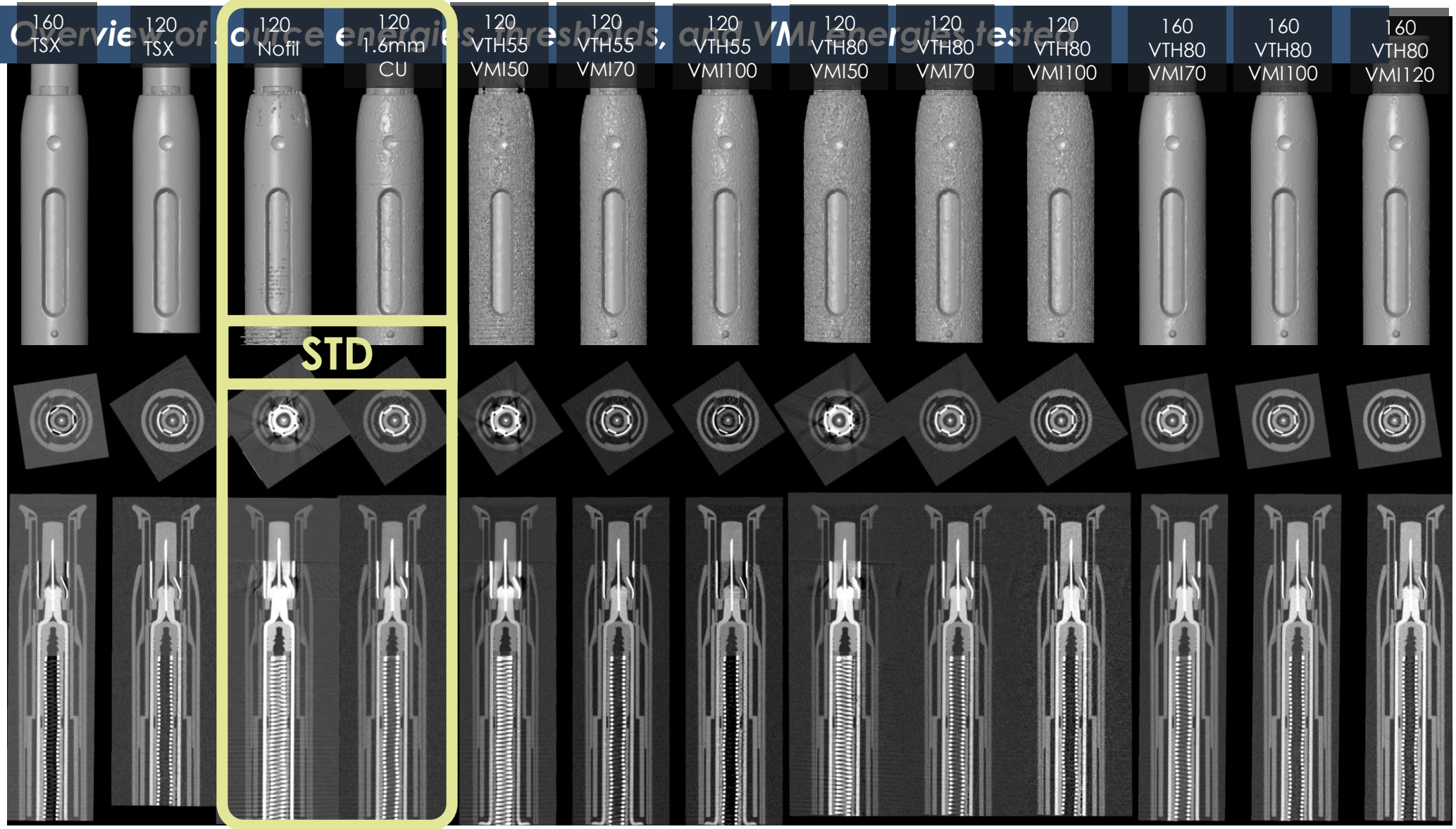

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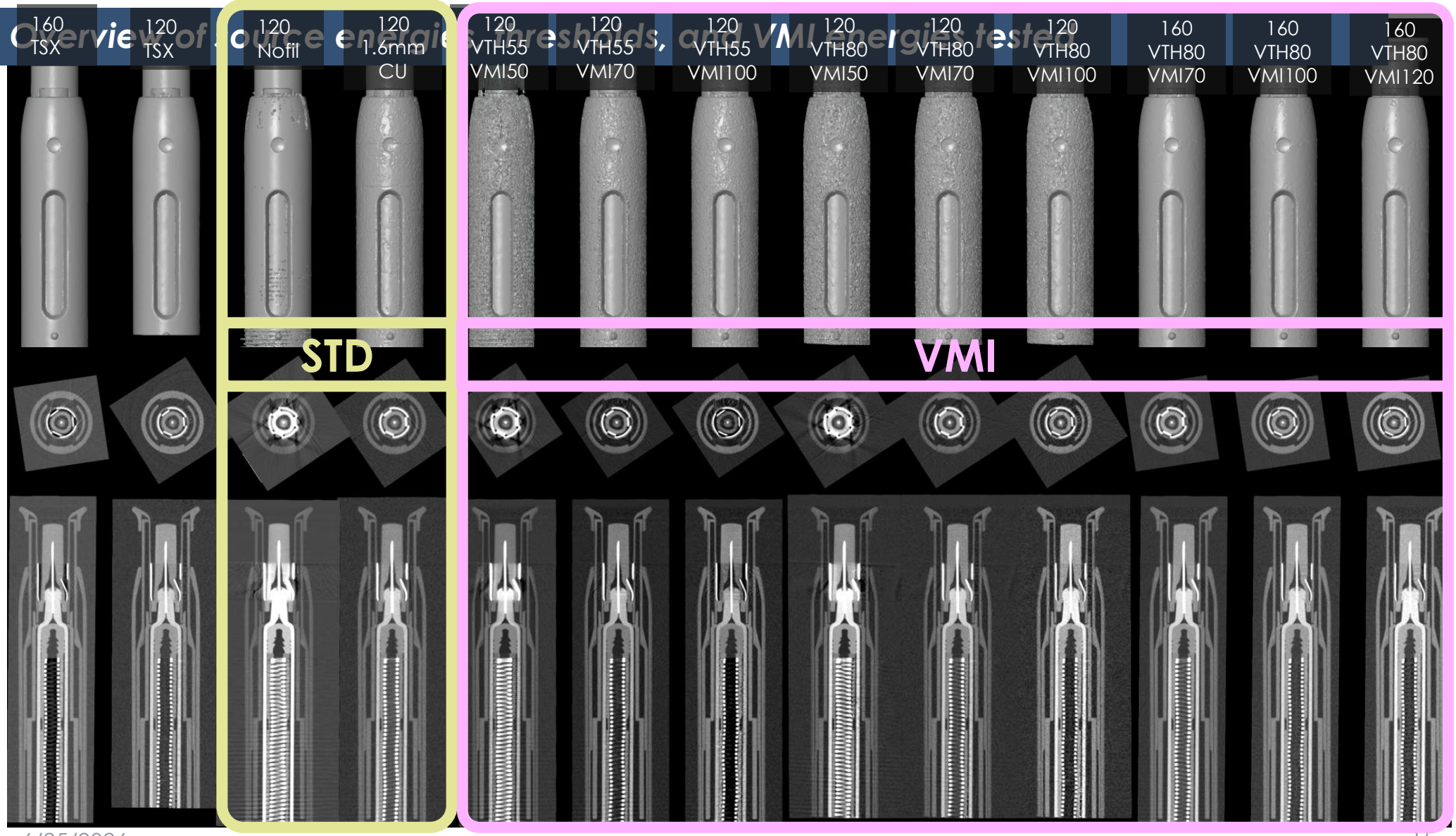

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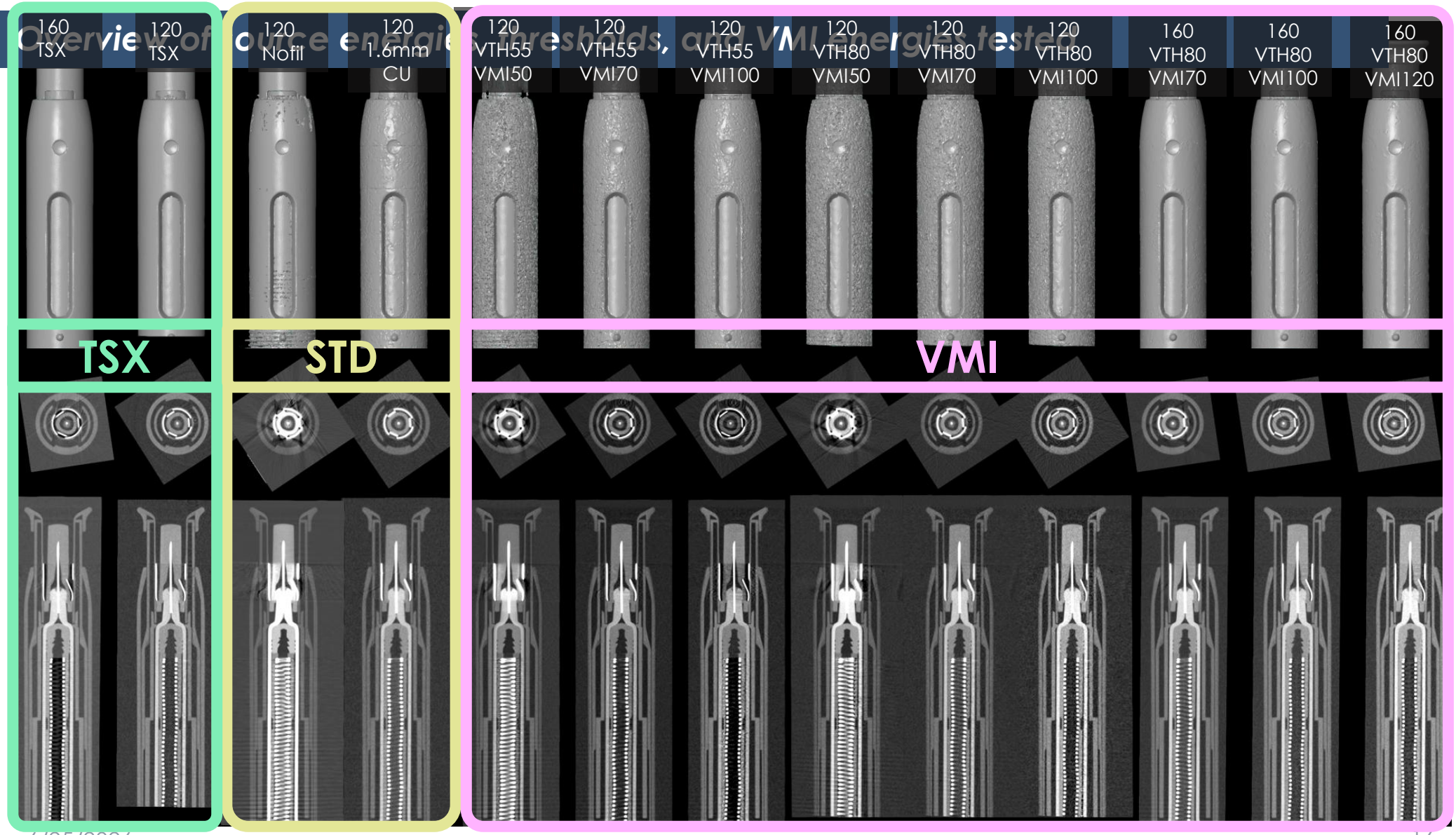


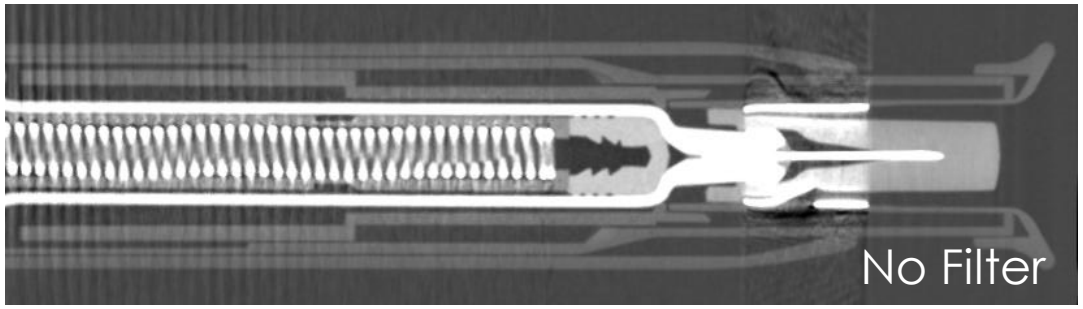
Reference: Single Energy + 1.6 mm Cu Filter

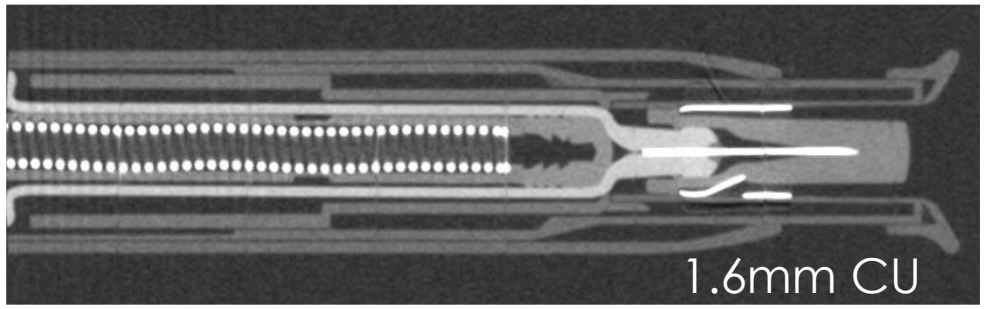
Establishing the baseline

Standard approach: 120 kV source with heavy Cu filtration

Significant dose absorbed by the filter — efficiency penalty

Residual beam hardening artifacts visible in CT slices:
→ Bright/dark streaks near high-density components
→ Boundary artifacts around the steel spring
→ Degradation in volume and surface in polymer regions





VMI Path: many tests – one best result

160 kV, 80 keV threshold, 100 keV VMI — surface and interior volume

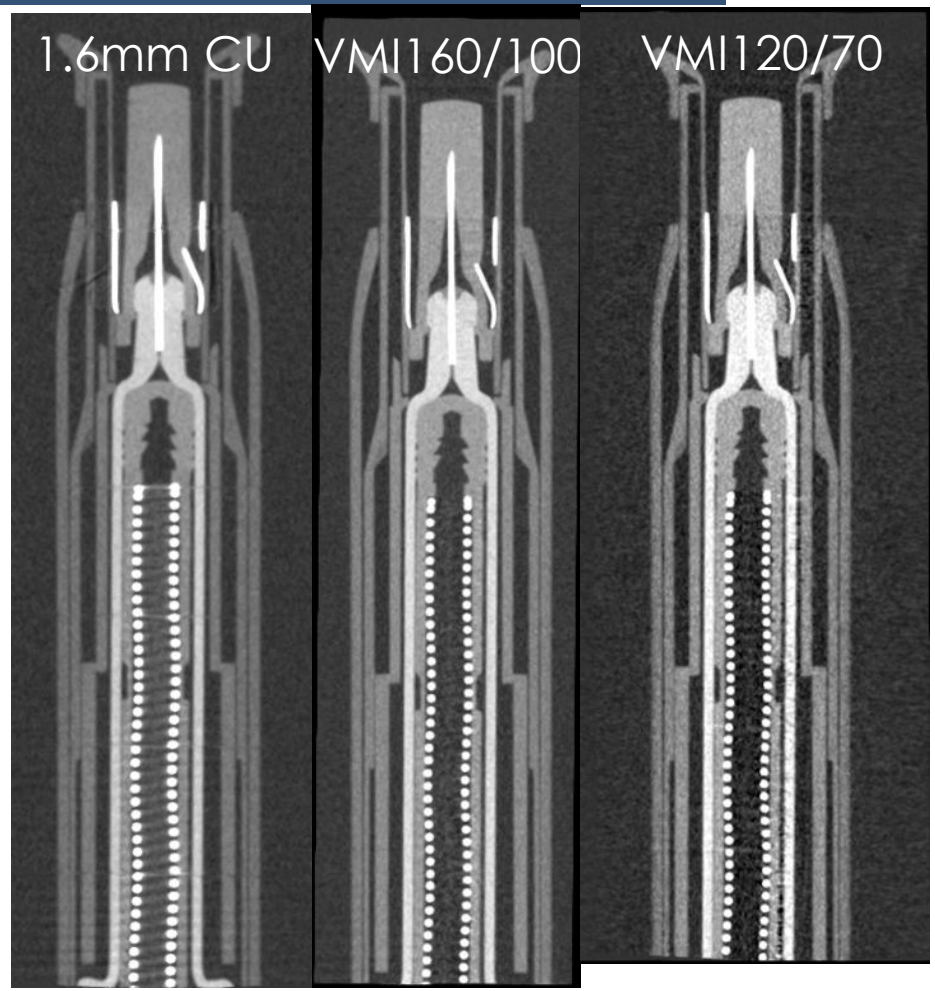
Best VMI Setting = **new recipe**
160 kV, 80 keV threshold, 100 keV VMI, no filter

→ Interior volume: best artifact reduction of all configurations tested

→ Steel spring region: artifacts largely resolved

→ Polymer SNR: good — higher than 1.6mm CU

→ Outer surface quality: good — better than filtered single-energy reference



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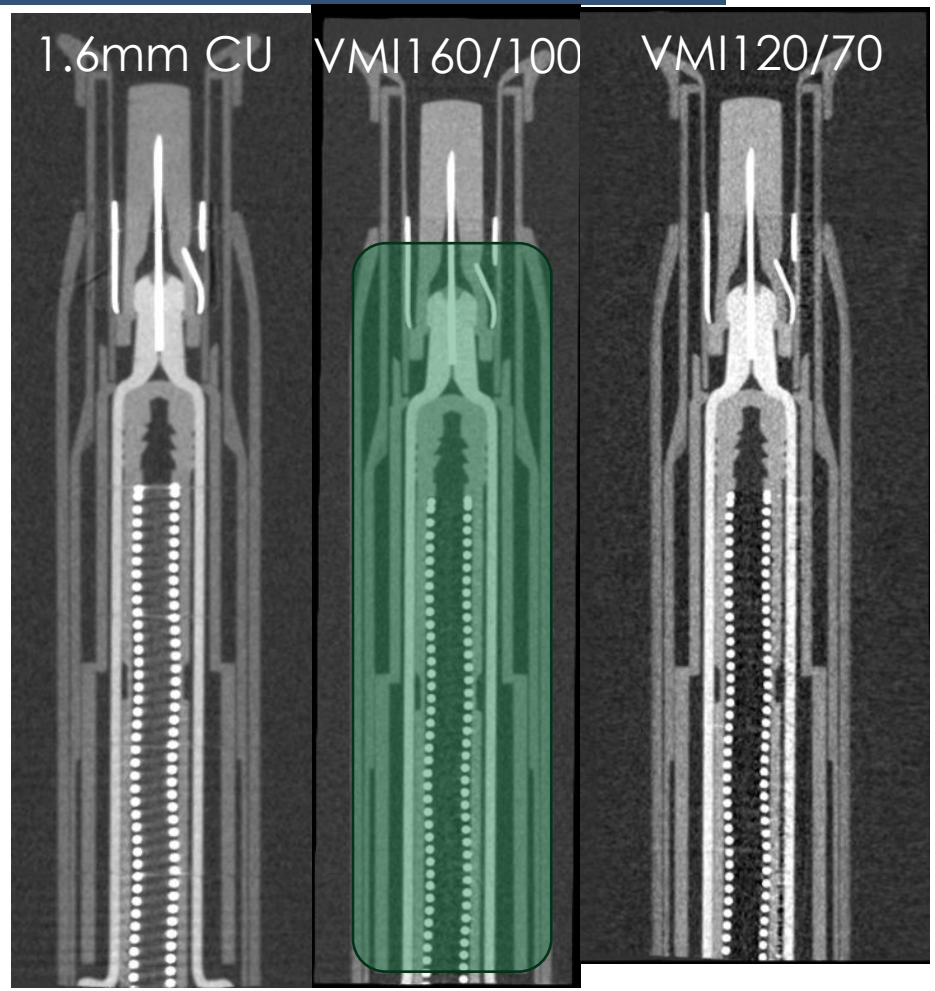

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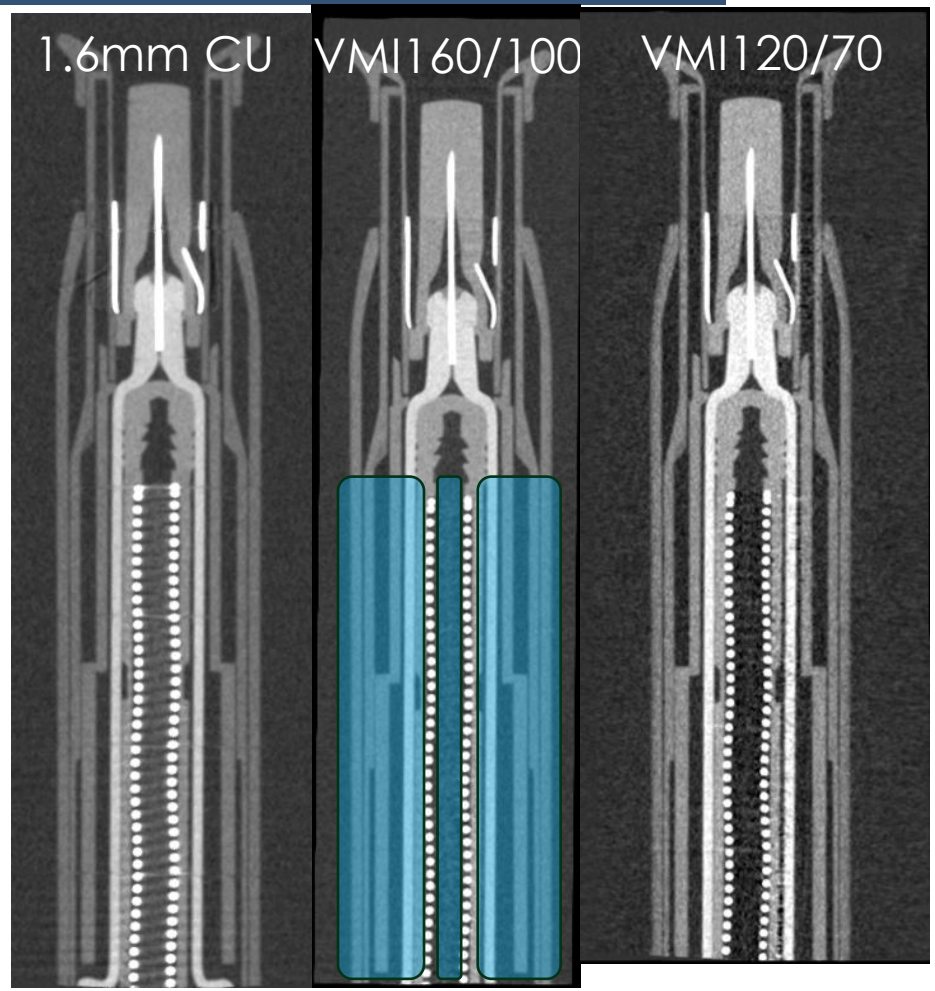

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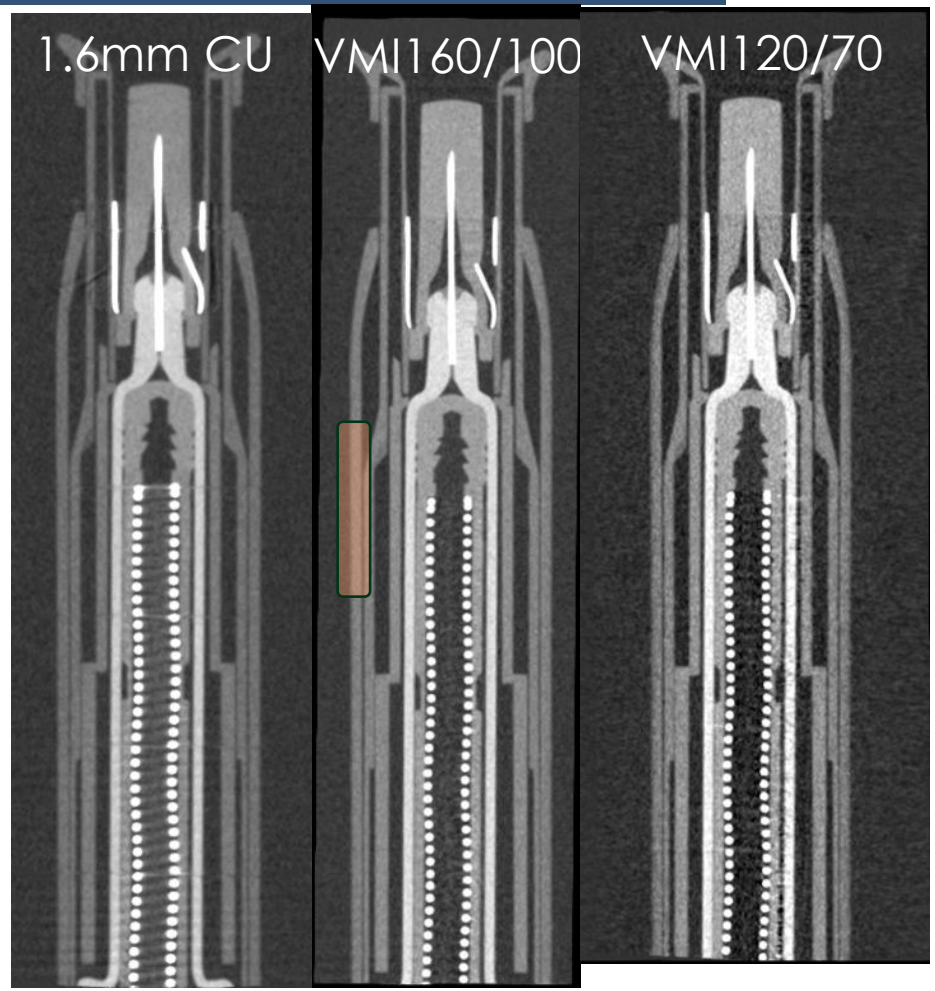

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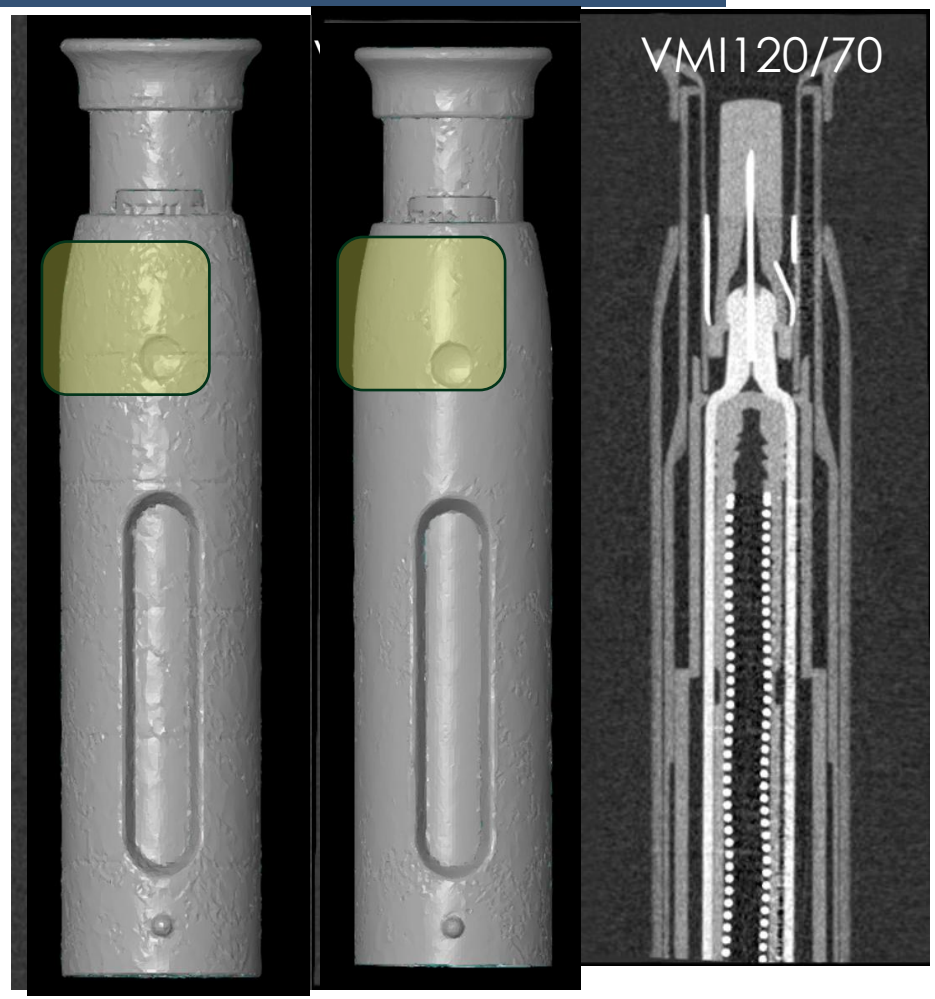

TrueSpectrum™: reducing the solution space

Recipes & Guides

Acquisition Parameters							Interior CT Volume		Interior surfaces	Exterior Surface	
Source kV	Source mA	Source Filter	Method	Threshold keV	VMI keV	TSx Setting	Int. artifacts	Int. noise	Overall quality	Ext. artifacts	Ext. crispness
120	1.2	none	Single energy TE	—	—	—	1	3	1	1	3
120	1.2	1.6mm Cu	Single energy TE	—	—	—	2	1.5	1.5	2	2
120	1.2	none	Dual energy VMI	55	50	—	1.5	2.5	1.5	1	1
120	1.2	none	Dual energy VMI	55	70	—	2	2	1.5	1	1
120	1.2	none	Dual energy VMI	55	100	—	2	1.5	2	1	1
120	1.2	none	Dual energy VMI	80	50	—	1.5	2	1	1	1
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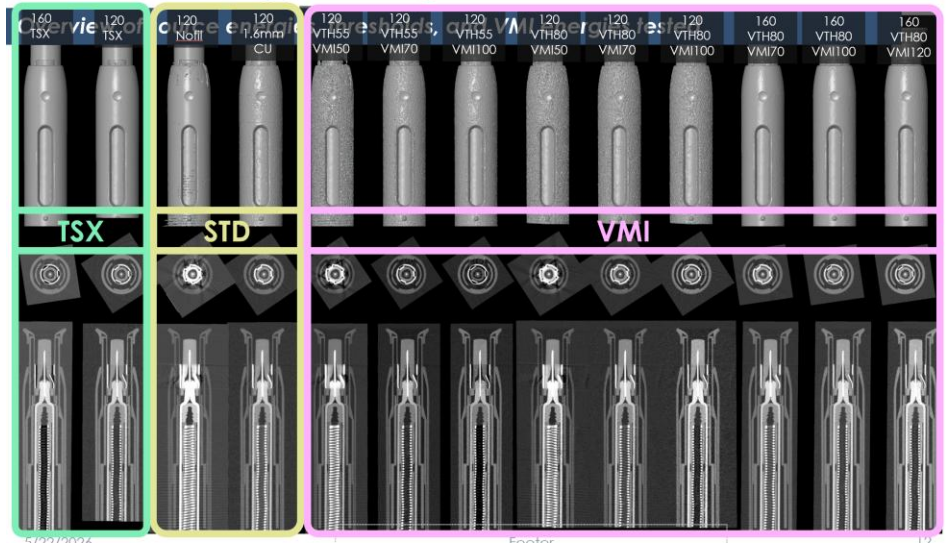
160	1	none	Dual energy VMI	80	70	—	2	2	2	2	2
160	1	none	Dual energy VMI	80	100	—	3 ★	2	2.5	2	2
160	1	none	Dual energy VMI	80	120	—	2.5	1.5	2.5	2	2
120	1.2	none	Dual energy TSx	80	—	w3x3, σ1	2.75	2	2.5	3 ★	3 ★
160	1	none	Dual energy TSx	80	—	w3x3, σ1	2	2	3 ★	3 ★	3 ★

Scale: 1 = poor | 2 = acceptable | 3 = best ★ = best in category

All Dual-Energy Settings Tested



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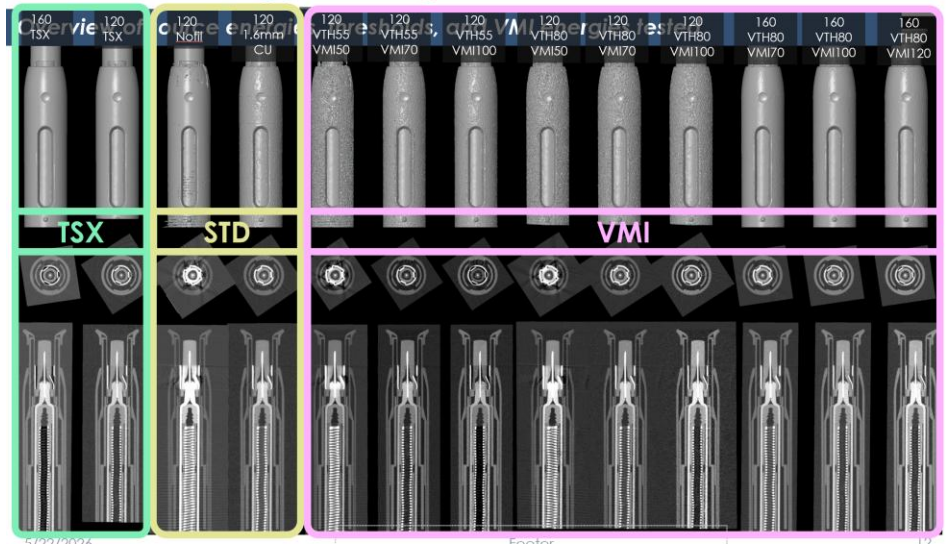

TrueSpectrum

RECIPE

TrueSpectrum™: reducing the solution space

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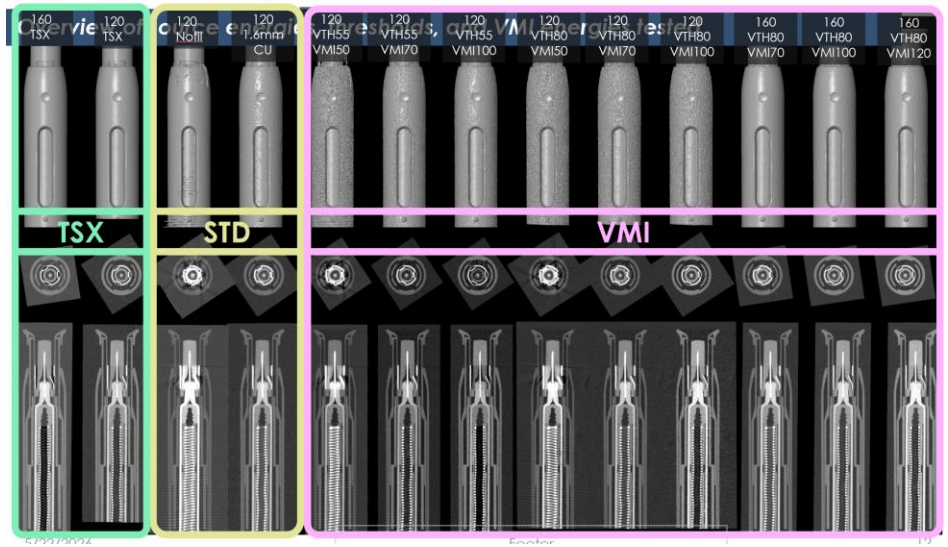
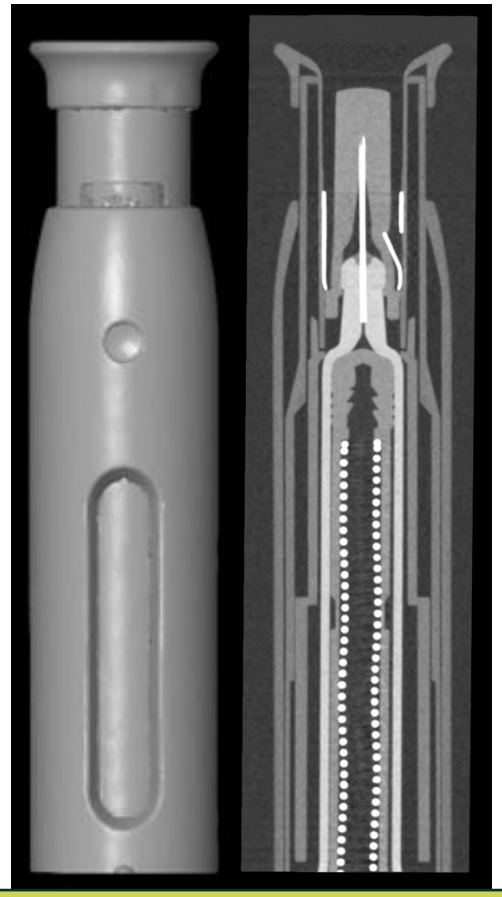


TrueSpectrum

RECIPE



Vsource = 160 kV, no filter
Threshold = 80 keV
VMI Energy = 100 keV

VMI is hard. Even with True Spectrum Recipes.

…

OK.

VMI - you probably know about.

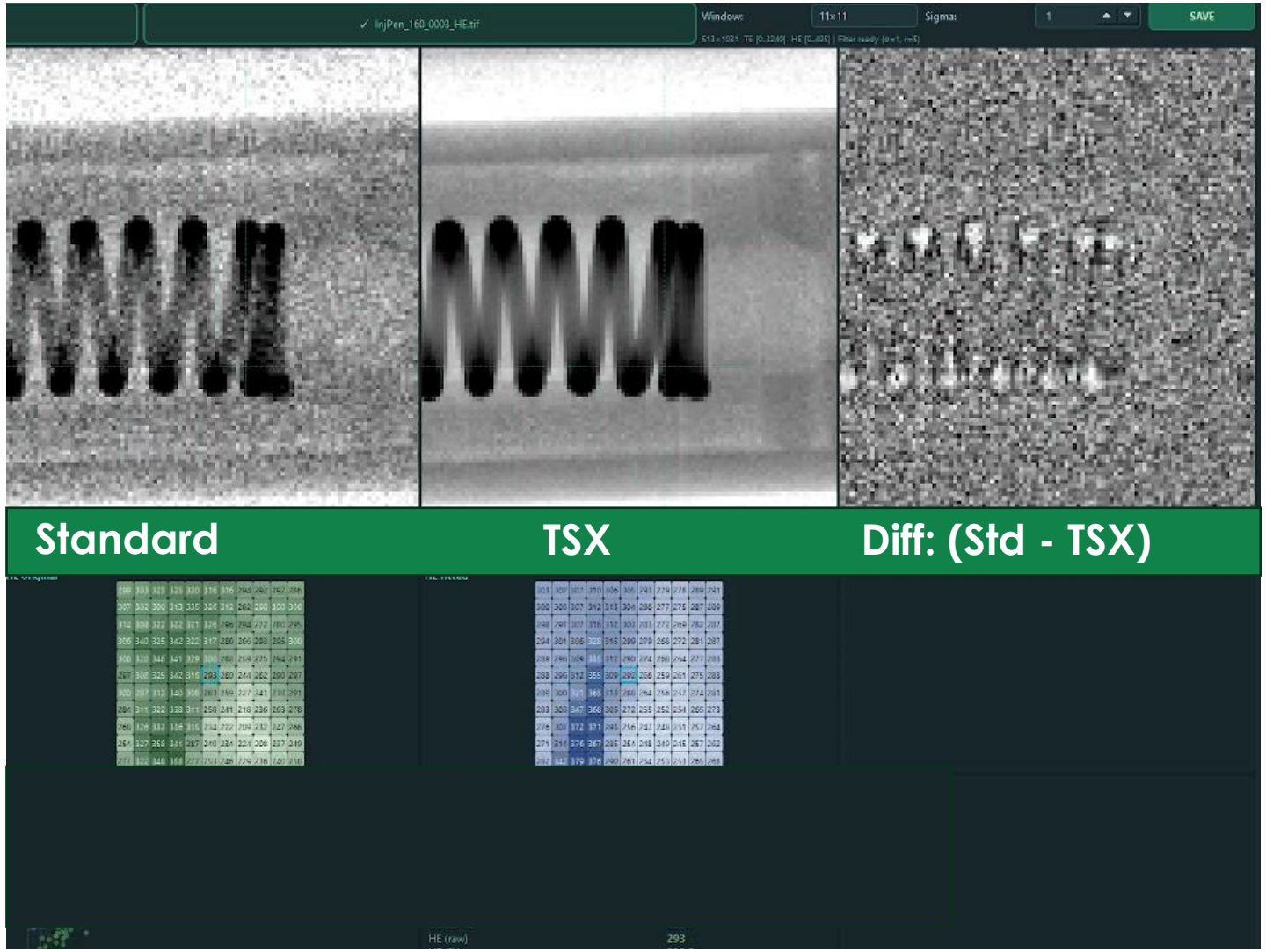
TrueSpectrum™ has it integrated - and helps you navigate.

VMI is effective – but even with help, it's complicated.

What else could we do??

True Spectrum Express (TSx): A Simpler Route

TSx: Demo Video



True Spectrum Express (TSX): A Simpler Route

No decomposition. No VMI. No parameters. One simple processing step.

Key observation:

HE (high-energy bin) images reconstruct nearly artifact-free on their own
→ High-energy photons suffer less beam hardening
→ But the HE images are noisy

Solution: TS Express (TSX): reconstruction of HE image
→ Proprietary Algorithm using Dual Energy Information

Pipeline: Dual-energy acquisition → TSX directly on Dual-E images → CT reconstruction
→ No material decomposition, no calibration materials, no VMI step required

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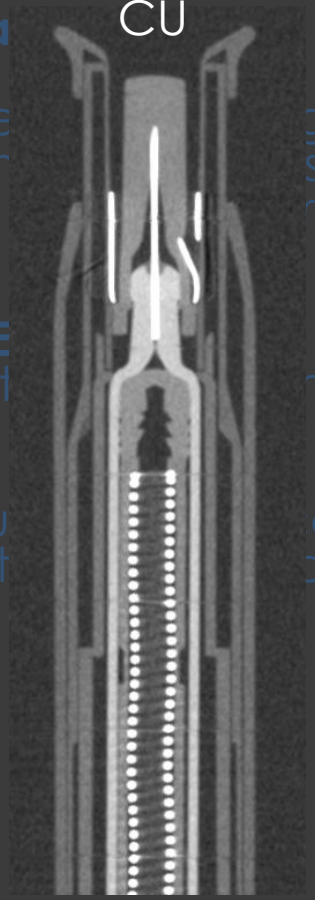
1.6mm
CU



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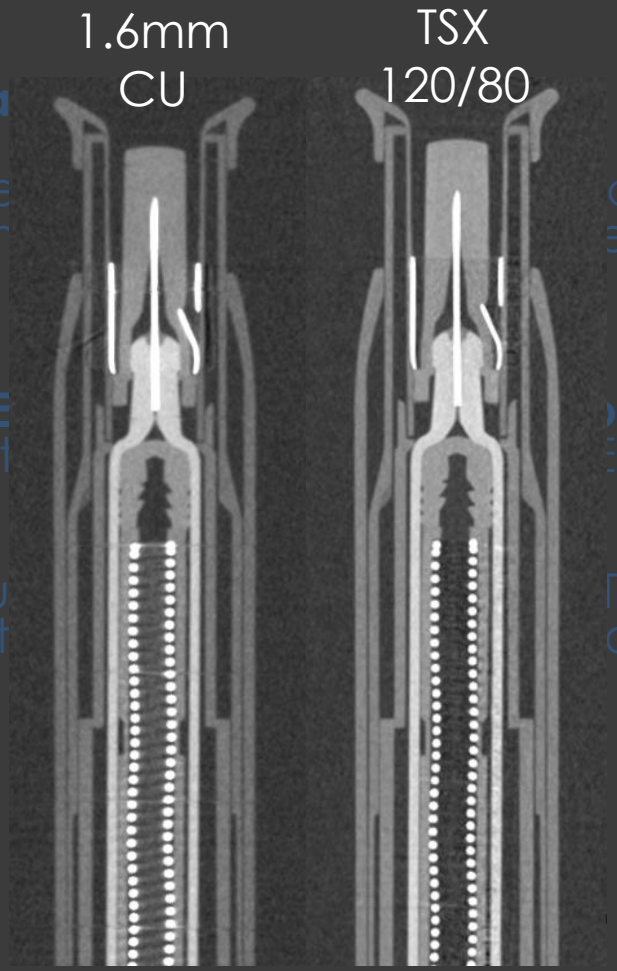
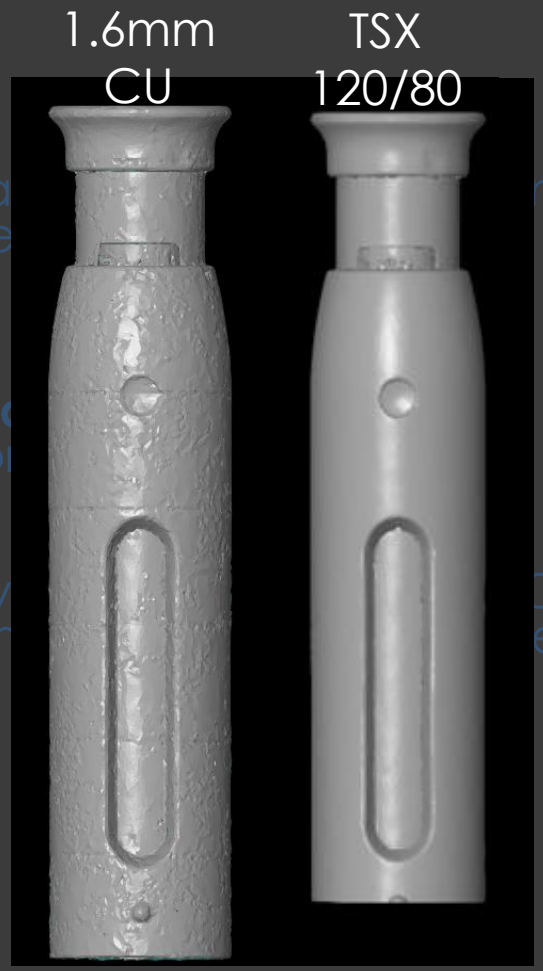
CT reconstruction
equired





VMI or True Spectrum Express (TSx)?

Same scan, two paths — choose by inspection task

Method	Int.art	Int.noise	Ext.art	Ext.crisp
120kV, no filter (single TE)	1	3	1	3
120kV, 1.6mm Cu (single TE)	2	1.5	2	2
120kV VMI 80/100keV (best)	2.5	1	1	1
160kV VMI 80/100keV	**3 ★**	**2**	**2**	**2**
120kV TSX ArgV2.76	**2.5**	**2**	**3 ★**	**3 ★**

Scale: 1 = poor, 2 = acceptable, 3 = best

→ **160kV VMI: best for interior volume inspection (NDT)**

→ **TSX: best for exterior surface metrology**

TSX available for early adopters — ask us

VMI or True Spectrum Express (TSx)?

Same scan, two paths — choose by inspection task

VMI
120/70

Method		Int.art	Int.noise	Ext.art	Ext.crisp
120kV, r		1	3	1	3
120kV, 1	TE)	2	1.5	2	2
120kV V	est)	2.5	1	1	1
160kV V		**3 ★**	**2**	**2**	**2**
120kV T		**2.5**	**2**	**3 ★**	**3 ★**

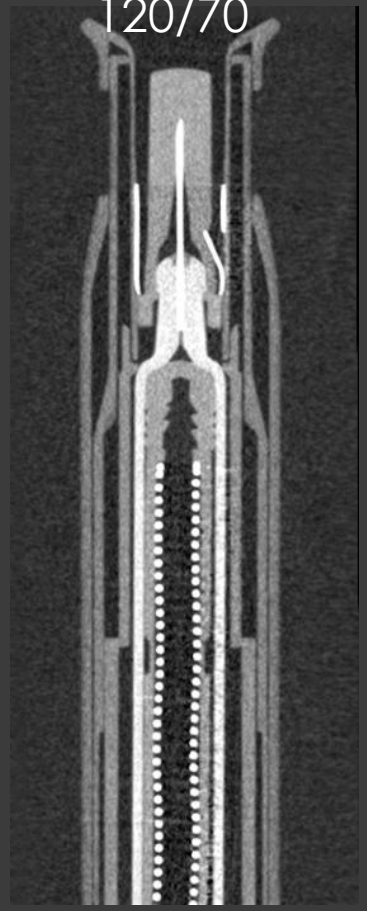
Scale: 1 table, 3 = best

→ **160kV terior volume inspection (NDT)**

→ **TSX: B urface metrology**

TSX ava dopters — ask us

VMI
120/70



VMI or True Spectrum Express (TSx)?

Same scan, two paths — choose by inspection task

VMI 120/70

VMI 160/100

Method	Int.c	e	Ext.art	Ext.crisp
120kV, r	1		1	3
120kV, 1	2	TE)	2	2
120kV V	2.5	est)	1	1
160kV V	**3 ★**		**2**	**2**
120kV T	**2.5**		**3 ★**	**3 ★**

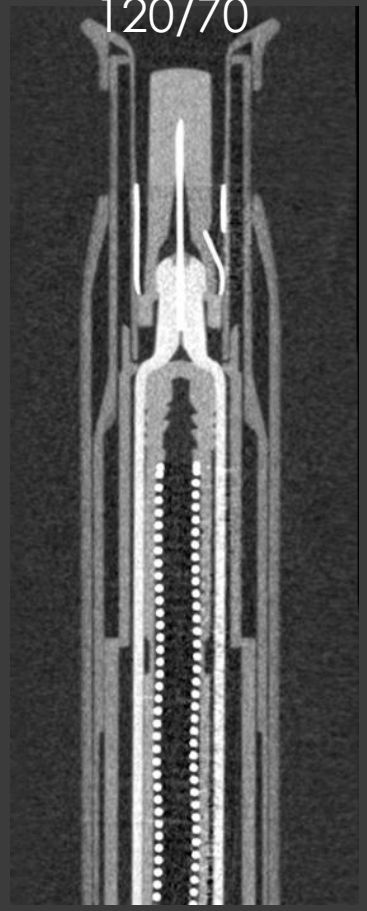
Scale: 1 table, 3 = best

→ **160kV** **terior volume i**)

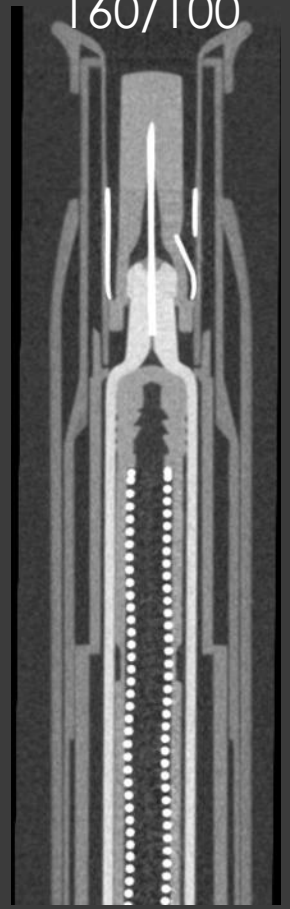
→ **TSX: b** **urface metrolo**

TSX ava dopters — ask

VMI 120/70



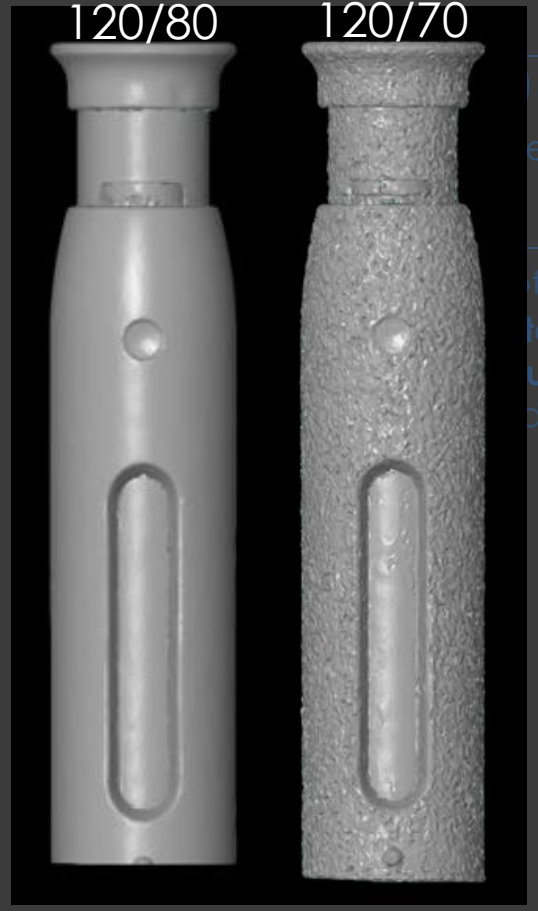
VMI 160/100



VMI or True Spectrum Express (TSx)?

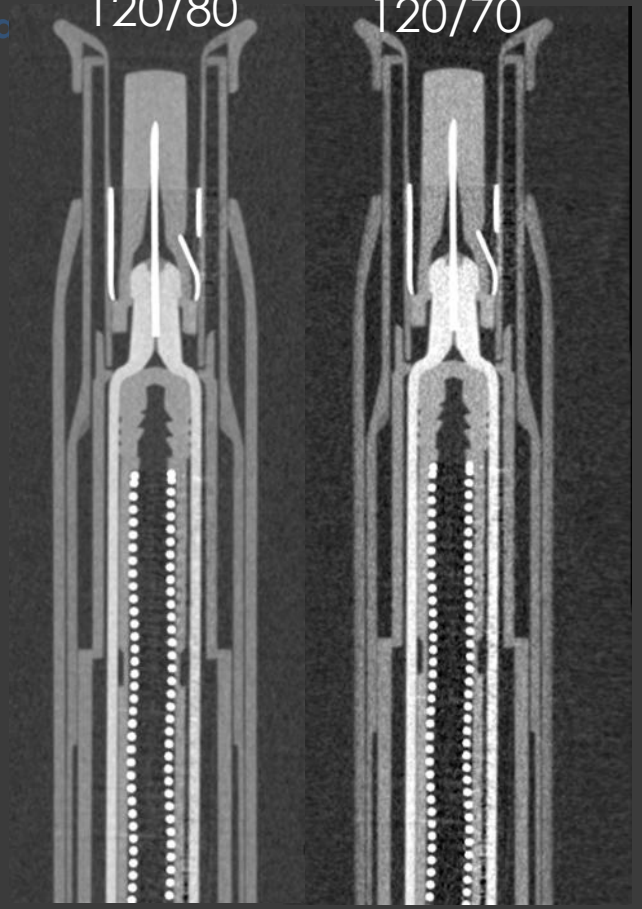
Same scan, two paths — choose by inspection task

TSx 120/80 | VMI 120/70

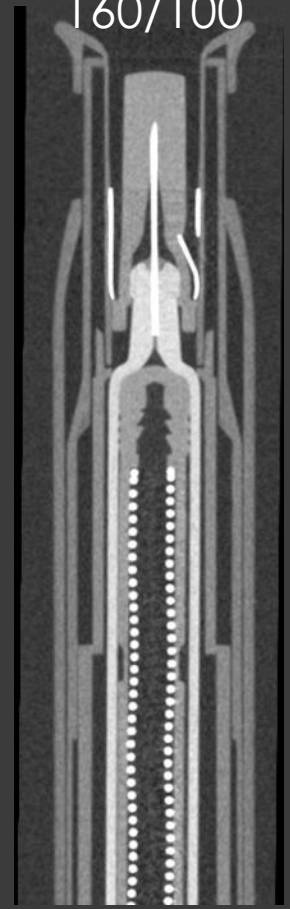


VMI 160/100

TSx 120/80 | VMI 120/70



VMI 160/100



VMI or True Spectrum Express (TSx)?

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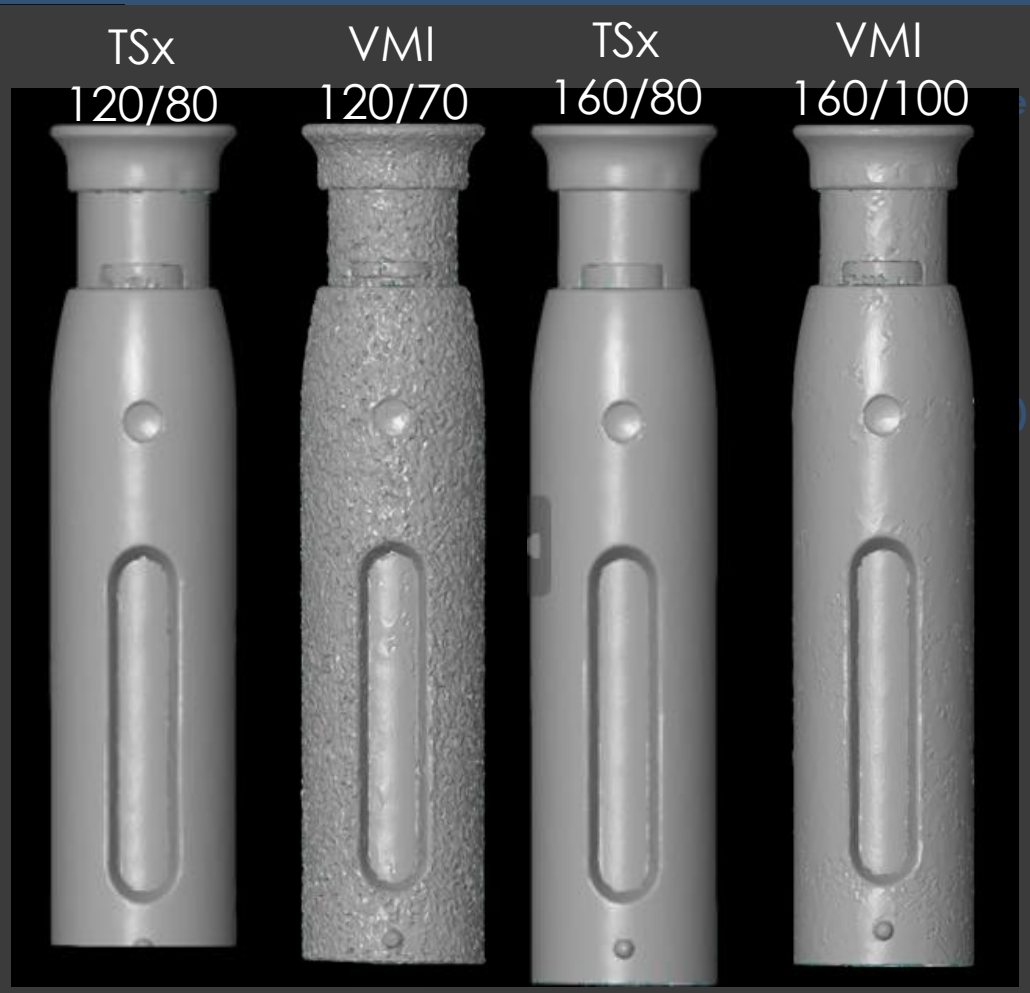

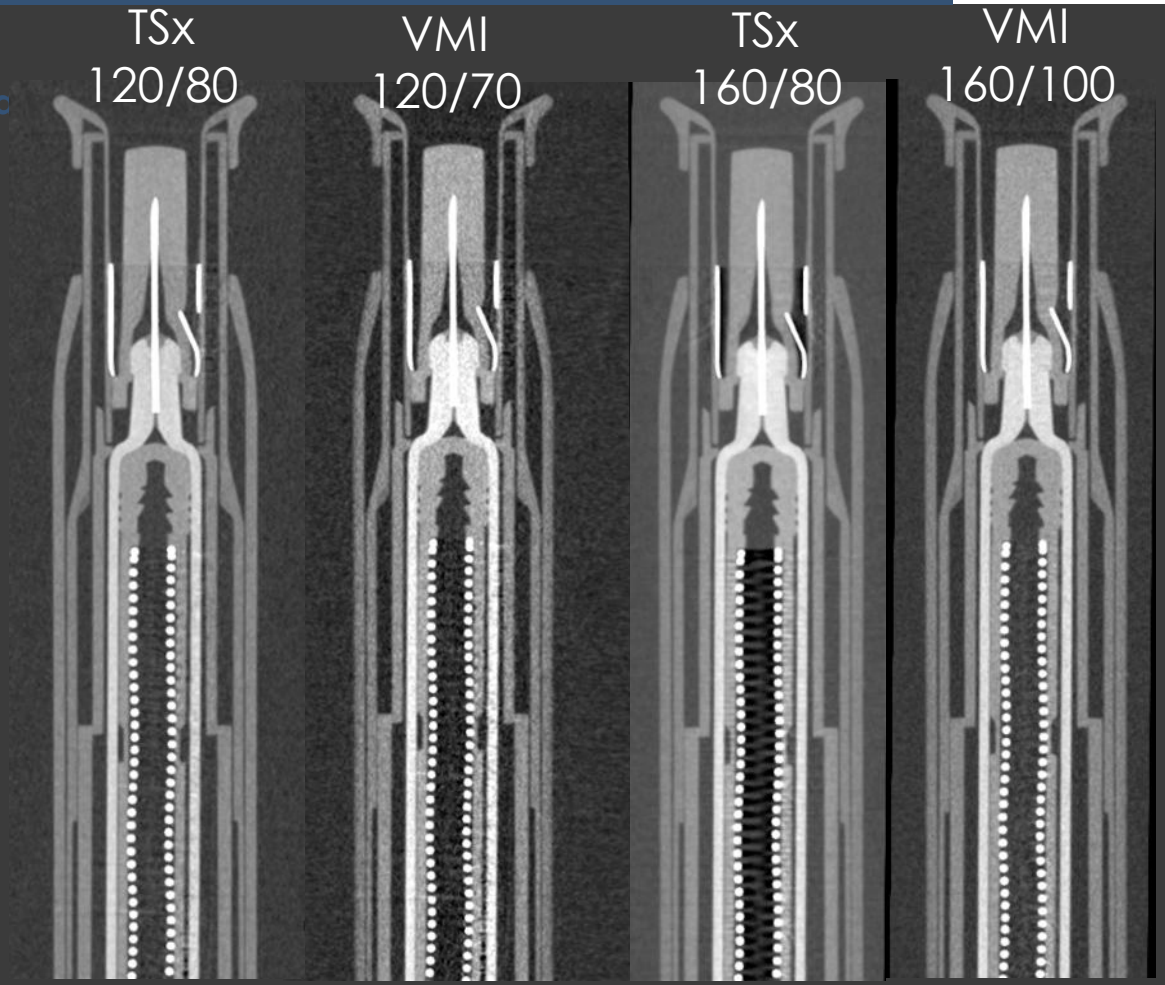

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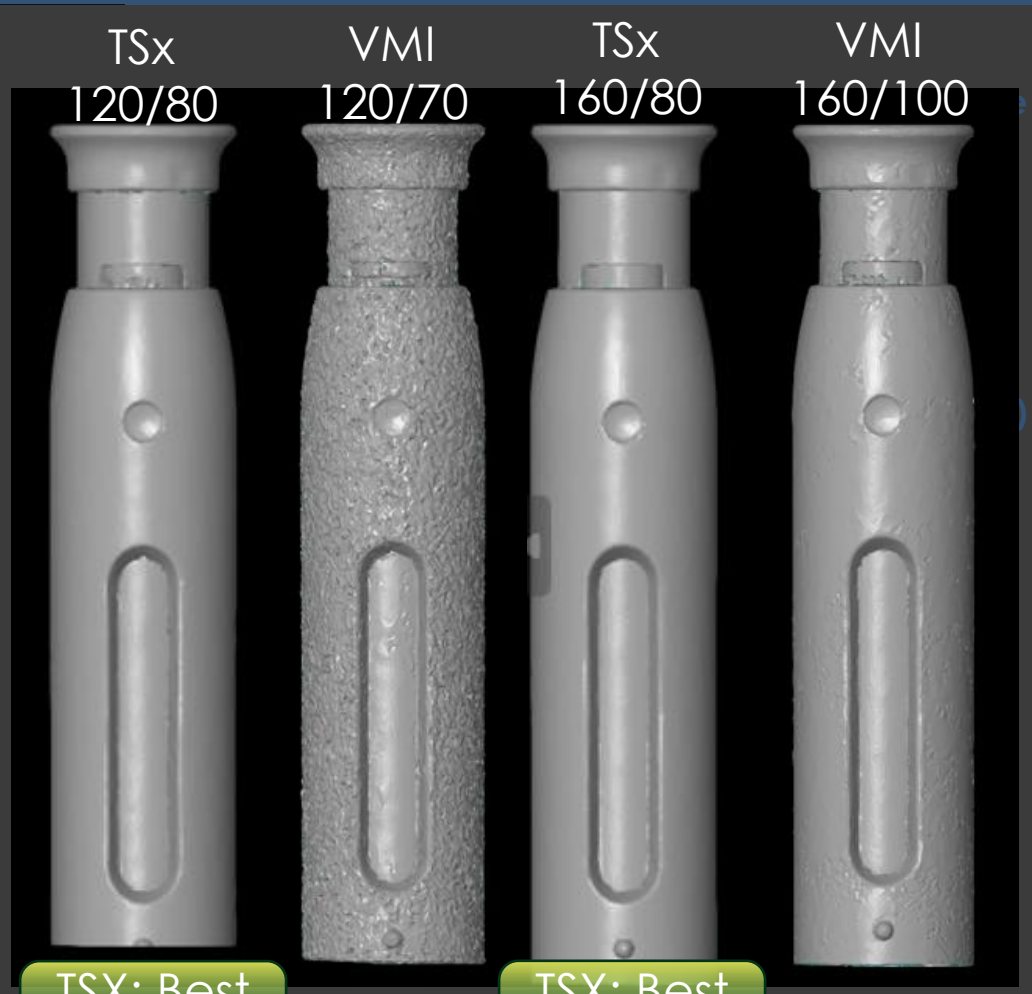

TSX: Best Surfaces

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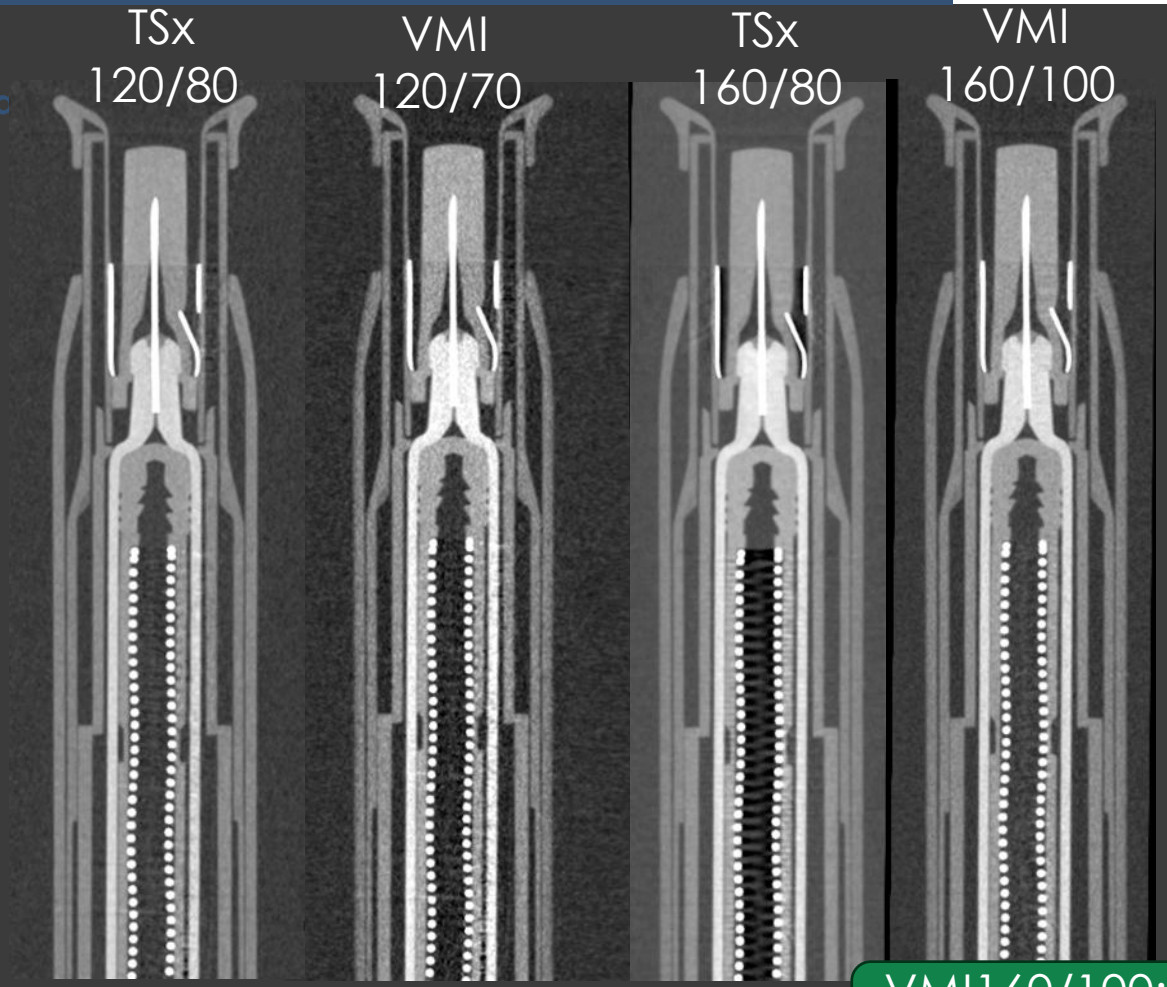
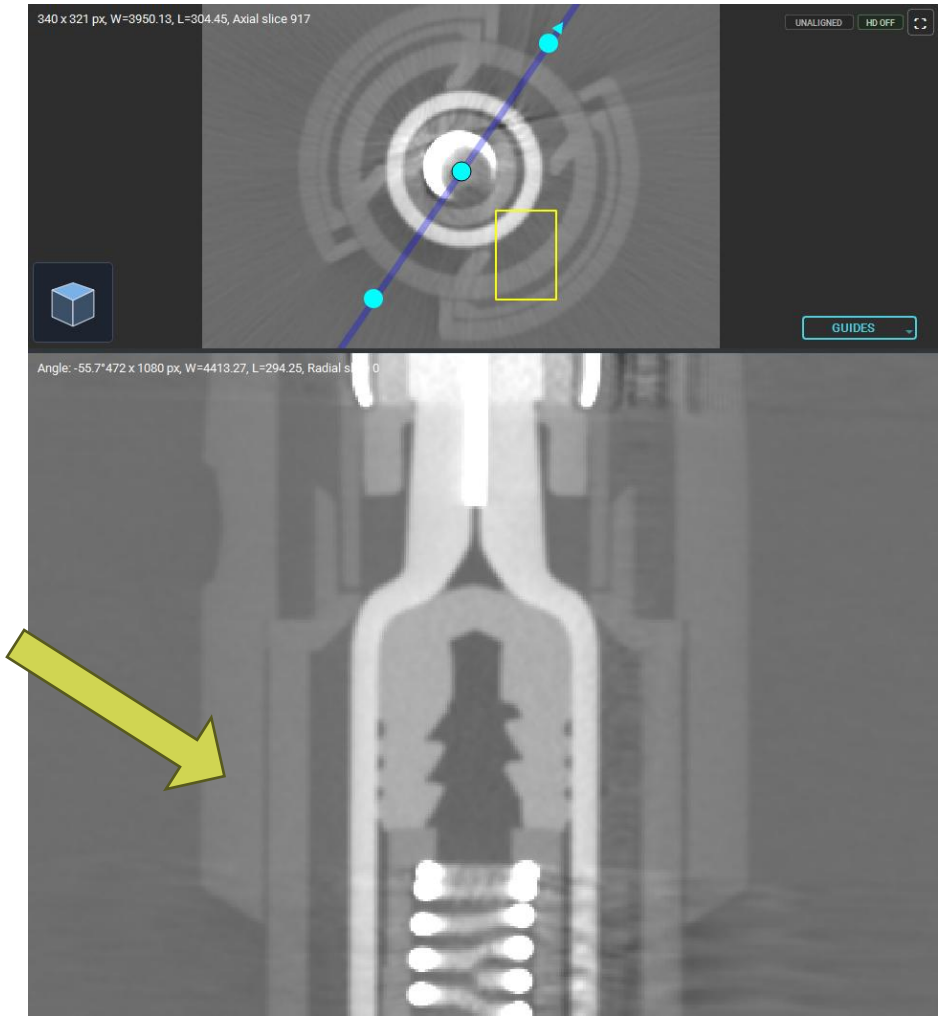


VMI160/100: Best Interior

Efficiency Gain: Filtration vs. Dual Energy

Breaking the trade-off



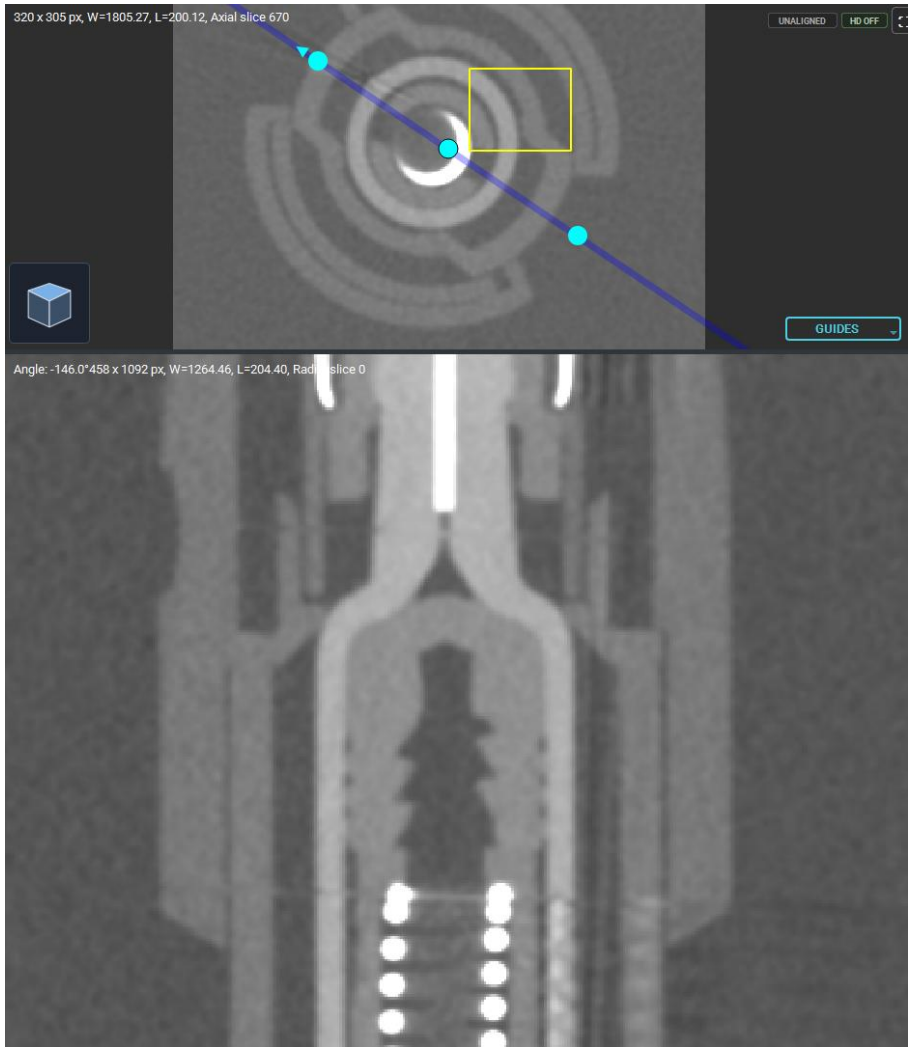
Outer Plastic: SNR

Note: ROI chosen so steel spring artifacts do NOT interfere with the SNR

120 Full Spectrum:
SNR 17.9

Efficiency Gain: Filtration vs. Dual Energy

Breaking the trade-off



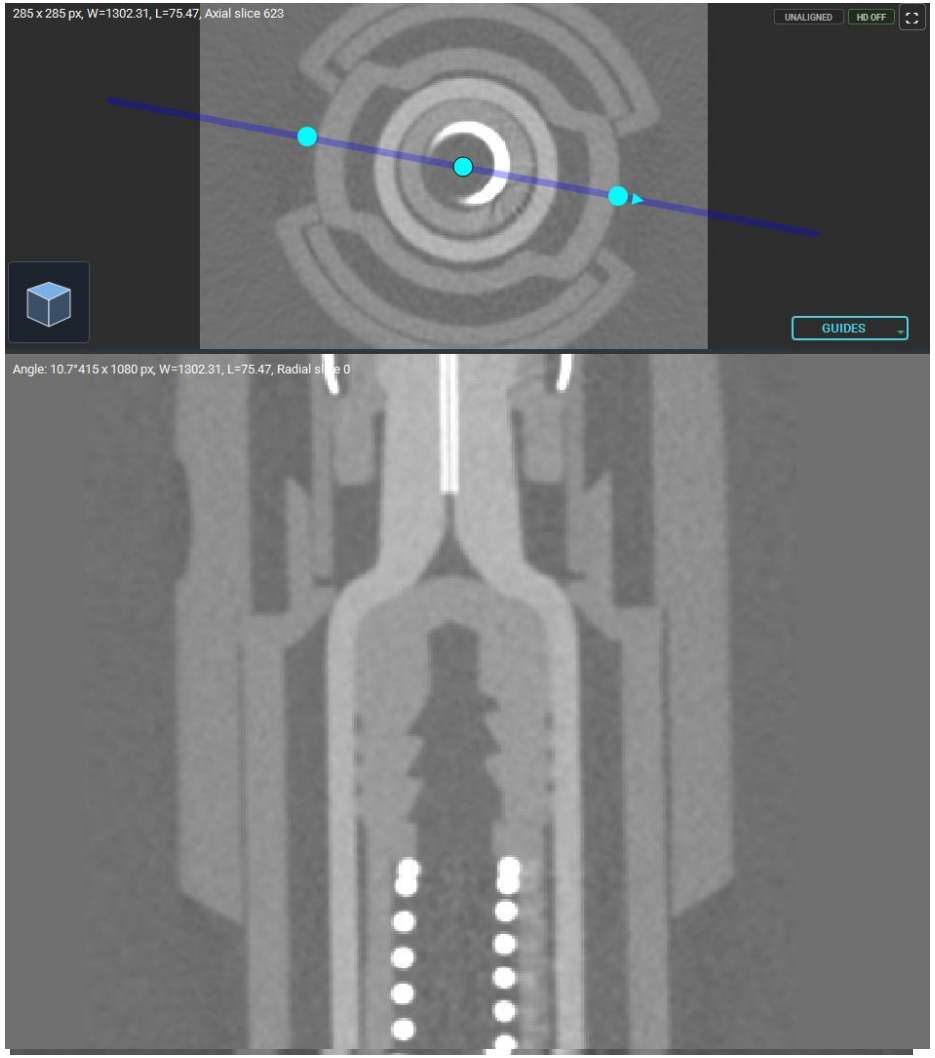
Outer Plastic: SNR

Note: ROI chosen so steel spring artifacts do NOT interfere with the SNR

120 CU1.6mm:
SNR 11.2

Efficiency Gain: Filtration vs. Dual Energy

Breaking the trade-off



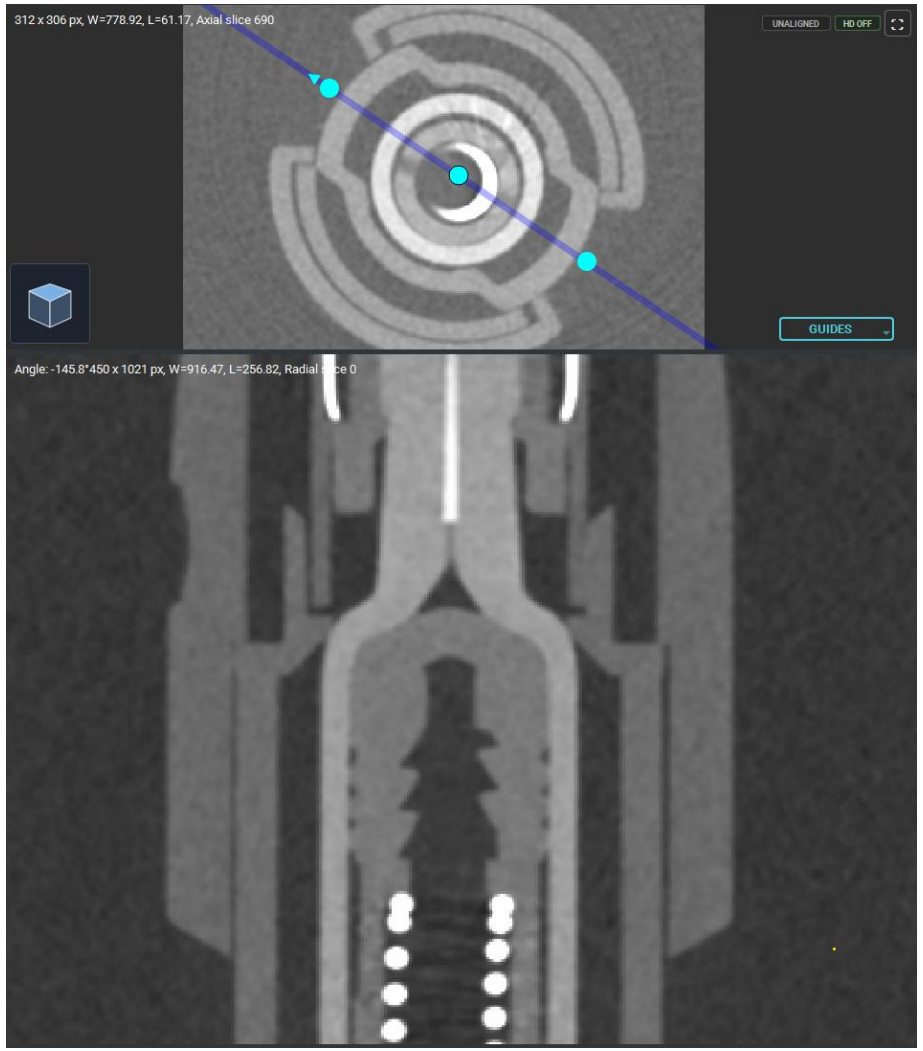
Outer Plastic: SNR

Note: ROI chosen so steel spring artifacts do NOT interfere with the SNR

VMI160/100:
SNR 14.3

Efficiency Gain: Filtration vs. Dual Energy

Breaking the trade-off



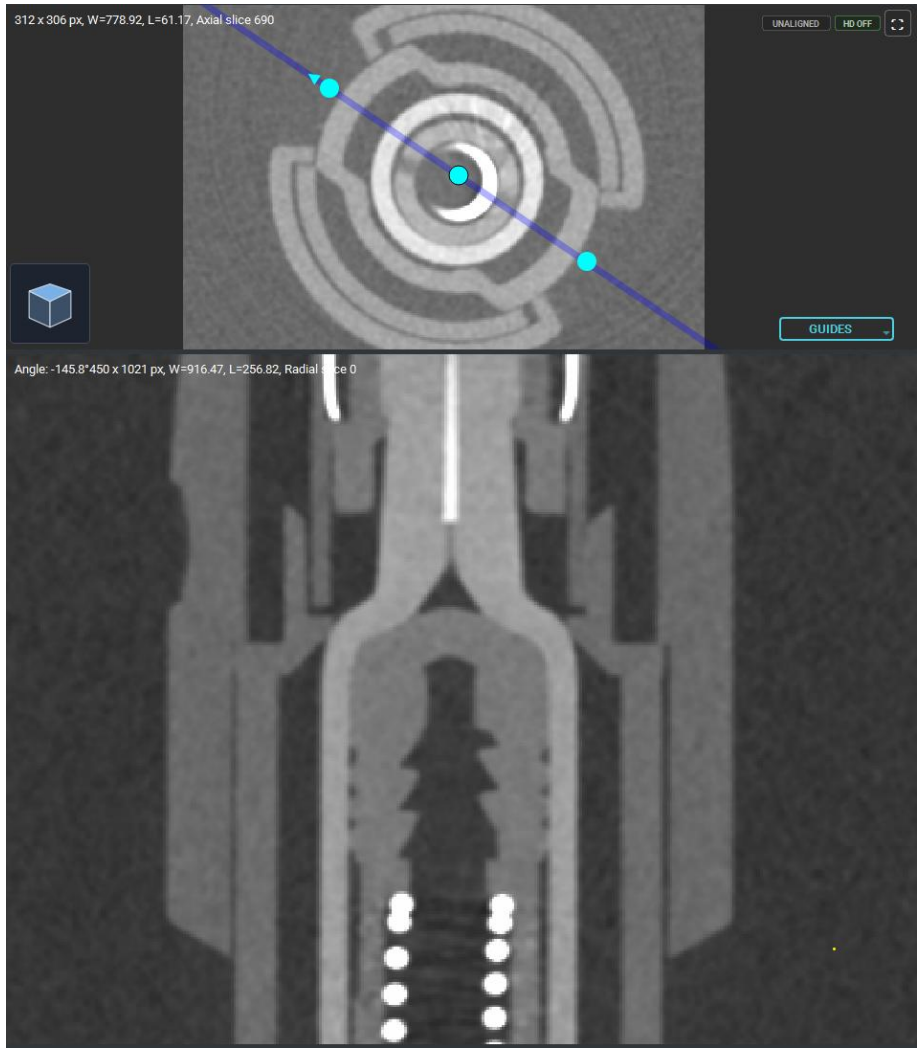
Outer Plastic: SNR

Note: ROI chosen so steel spring artifacts do NOT interfere with the SNR

TSX120/80:
SNR 19.9

Efficiency Gain: Filtration vs. Dual Energy

Breaking the trade-off



Outer Plastic: SNR

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120 Full Spectrum:
SNR 17.9

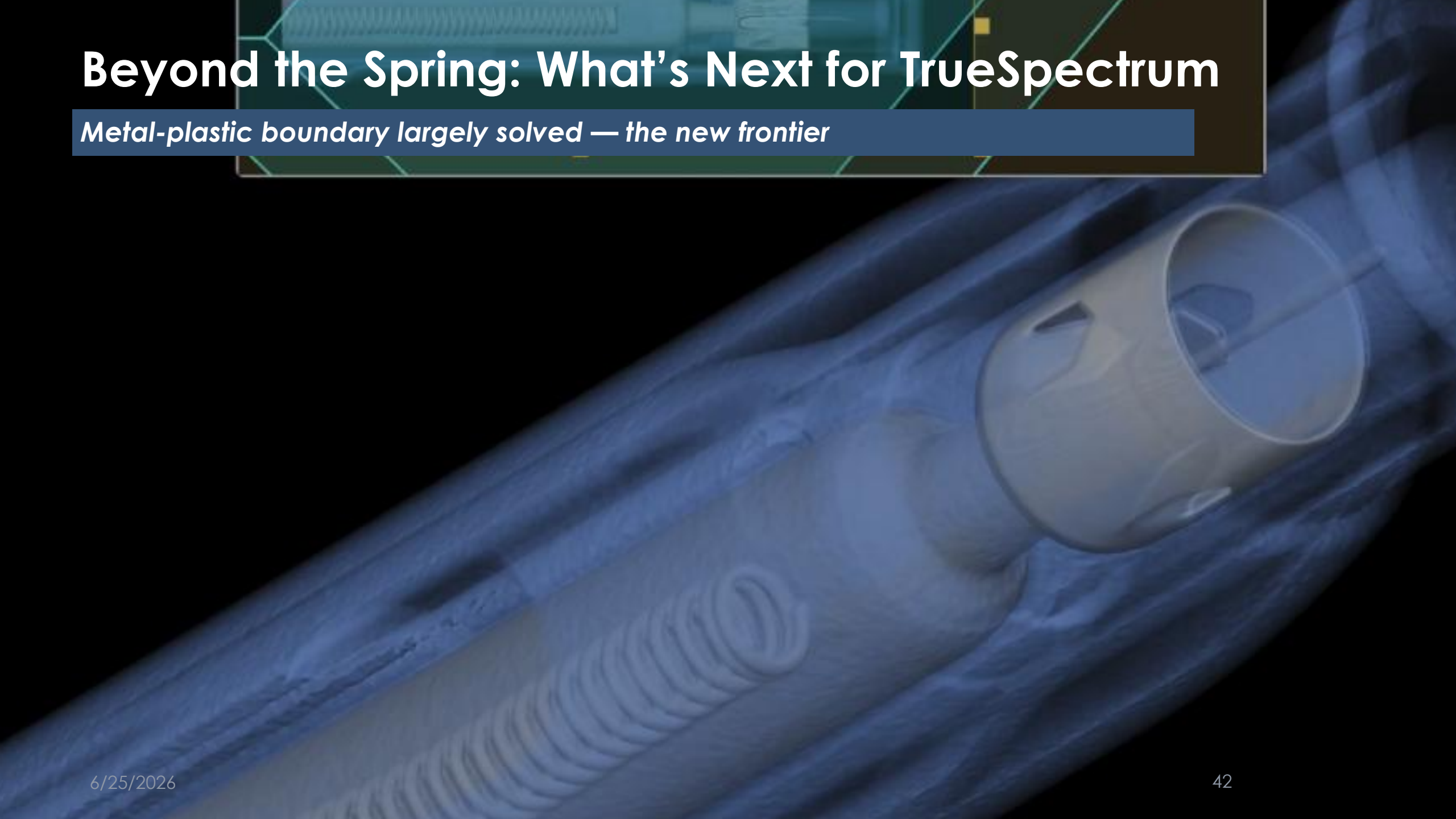
120 CU1.6mm:
SNR 11.2

VMI160/100:
SNR 14.3

TSX120/80:
SNR 19.9

Beyond the Spring: What's Next for TrueSpectrum

Metal-plastic boundary largely solved — the new frontier



Beyond the Spring: What's Next for TrueSpectrum

Metal-plastic boundary largely solved — the new frontier

Where we started: steel spring boundary artifacts were the hard problem

→ Extreme local density gradient at metal-to-polymer interface
→ Partial volume effects and noise amplification at spring geometry

Where we are now: largely solved for current object

→ 160 kV VMI: spring boundary artifacts resolved:
interior score 3/3, exterior 2

→ 120kV TSx: boundary artifacts substantially reduced
interior score 2.75/3, exterior 3

The new frontier: combining VMI and TSx

→ Can a combined pipeline deliver best interior AND best exterior from a single scan?

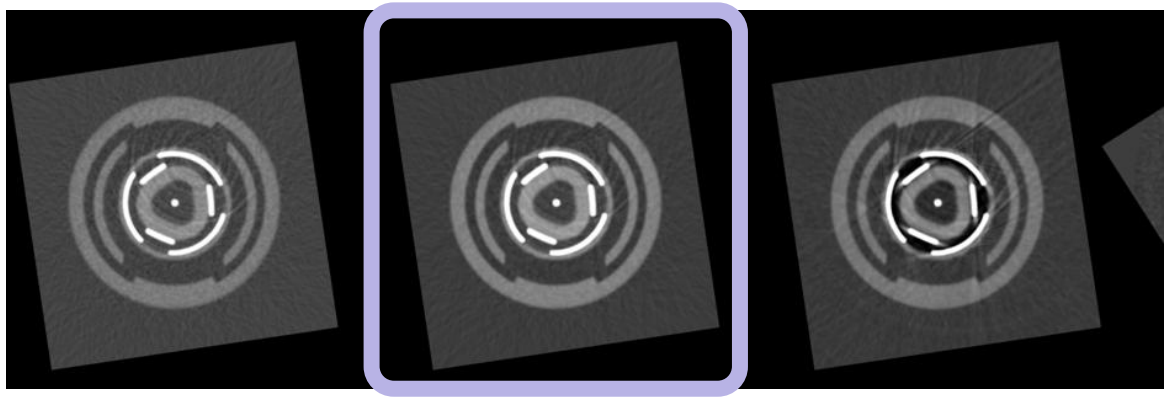
Beyond the Spring: What's Next for TrueSpectrum

Combined VMI+TSx pipeline, Broader object classes, TSx with Flat Panels

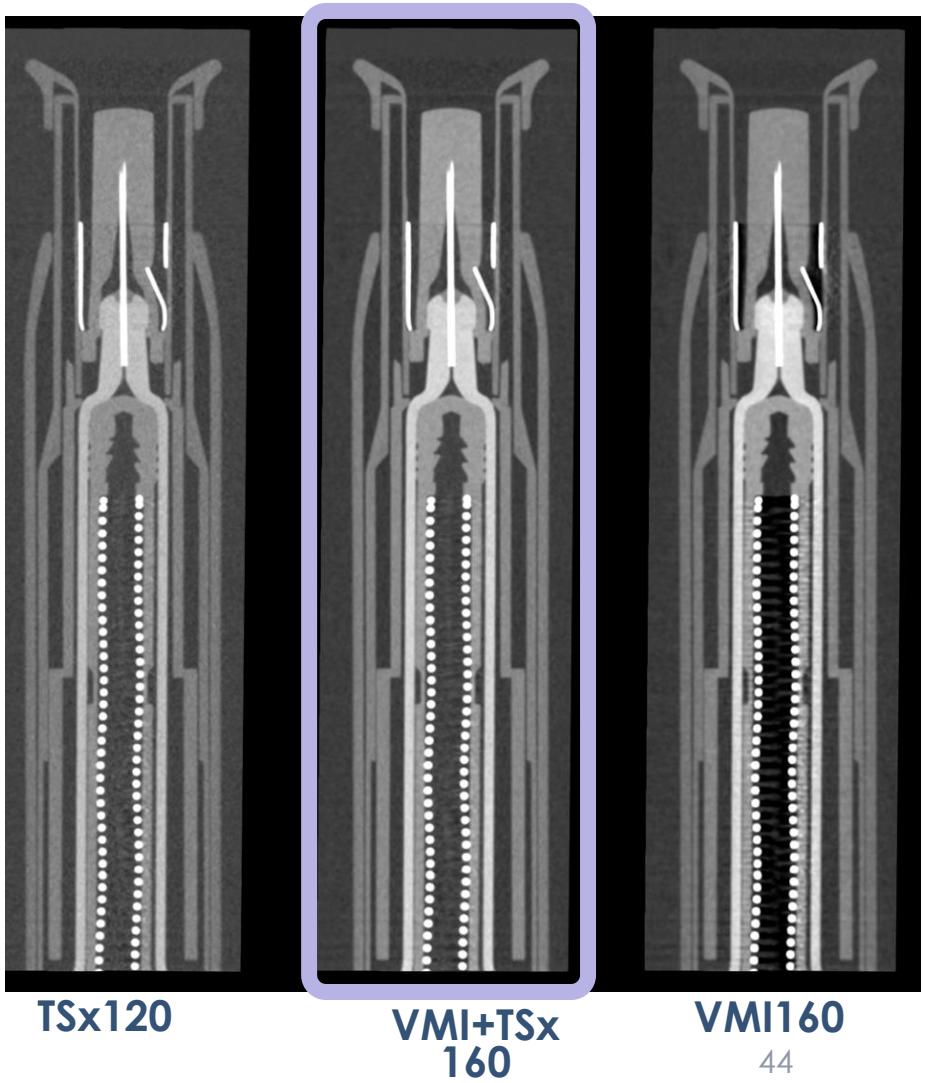
Combined VMI + TSx pipeline

→ Use TSx on images before decomposition

→ Target: score 3 interior AND score 3 exterior



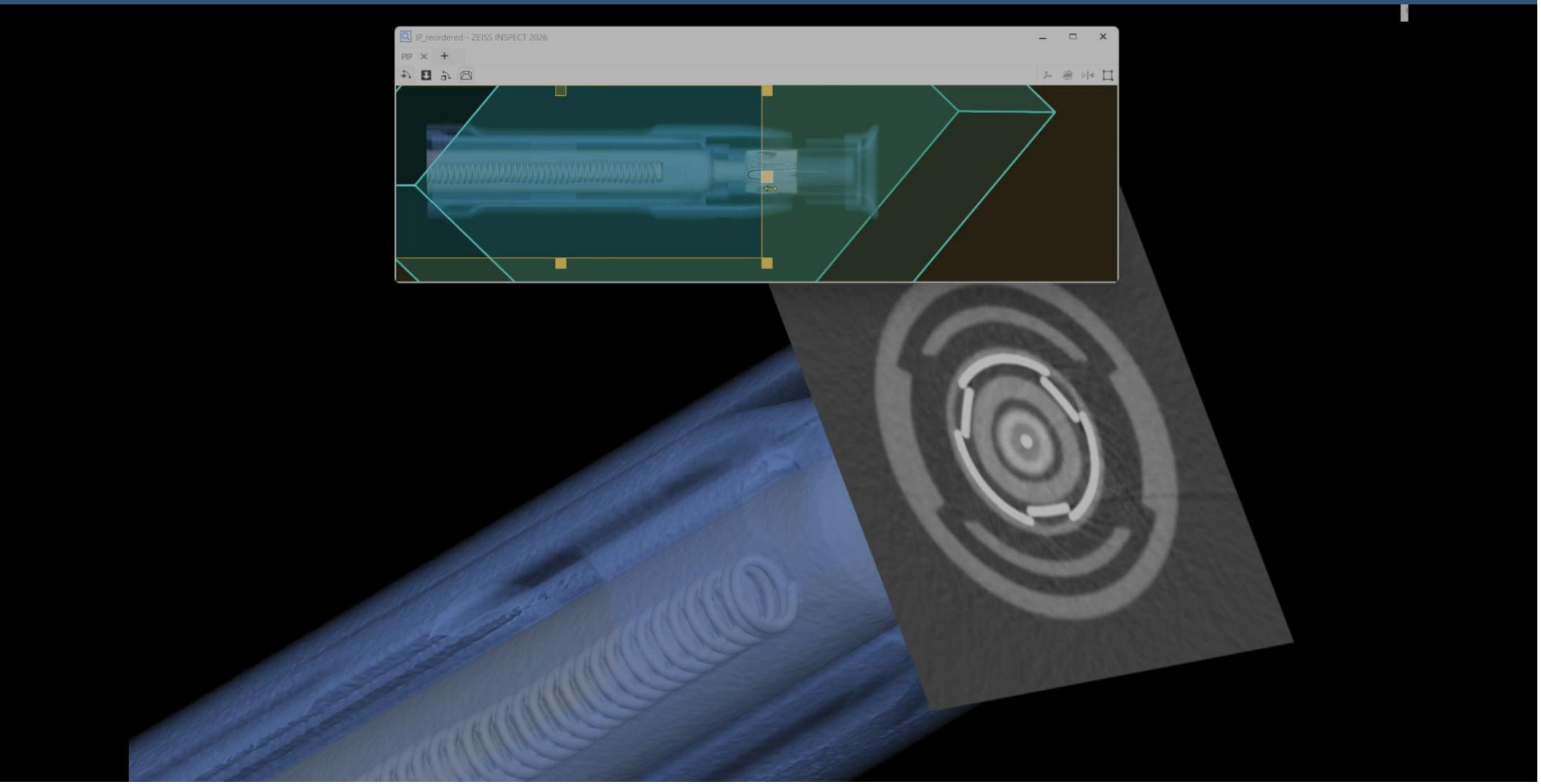
TSx120 | VMI+TSx 160 | VMI160



TSx120 | VMI+TSx 160 | VMI160

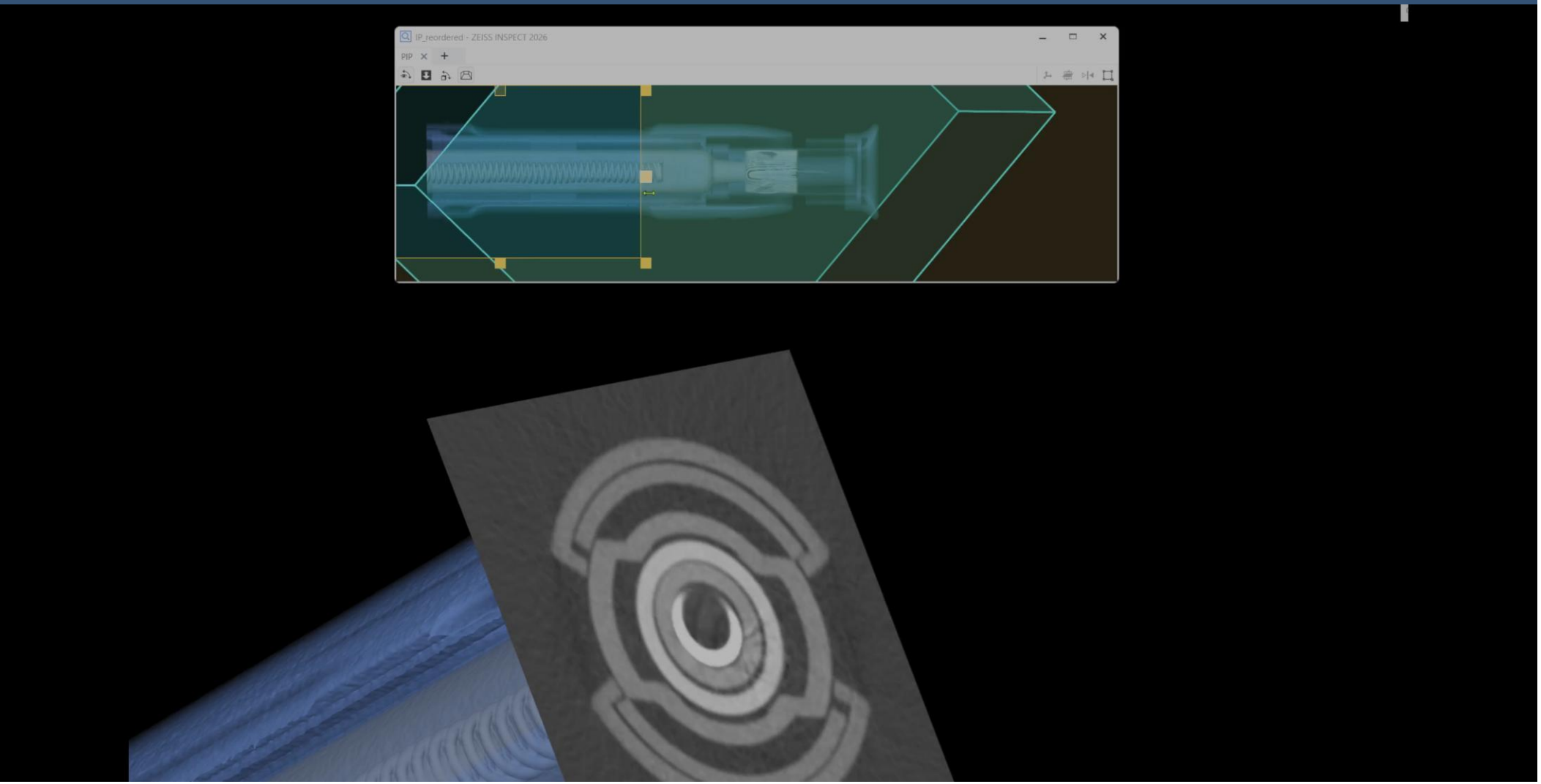
Beyond the Spring: What's Next for TrueSpectrum

Combined VMI+TSx pipeline: Video



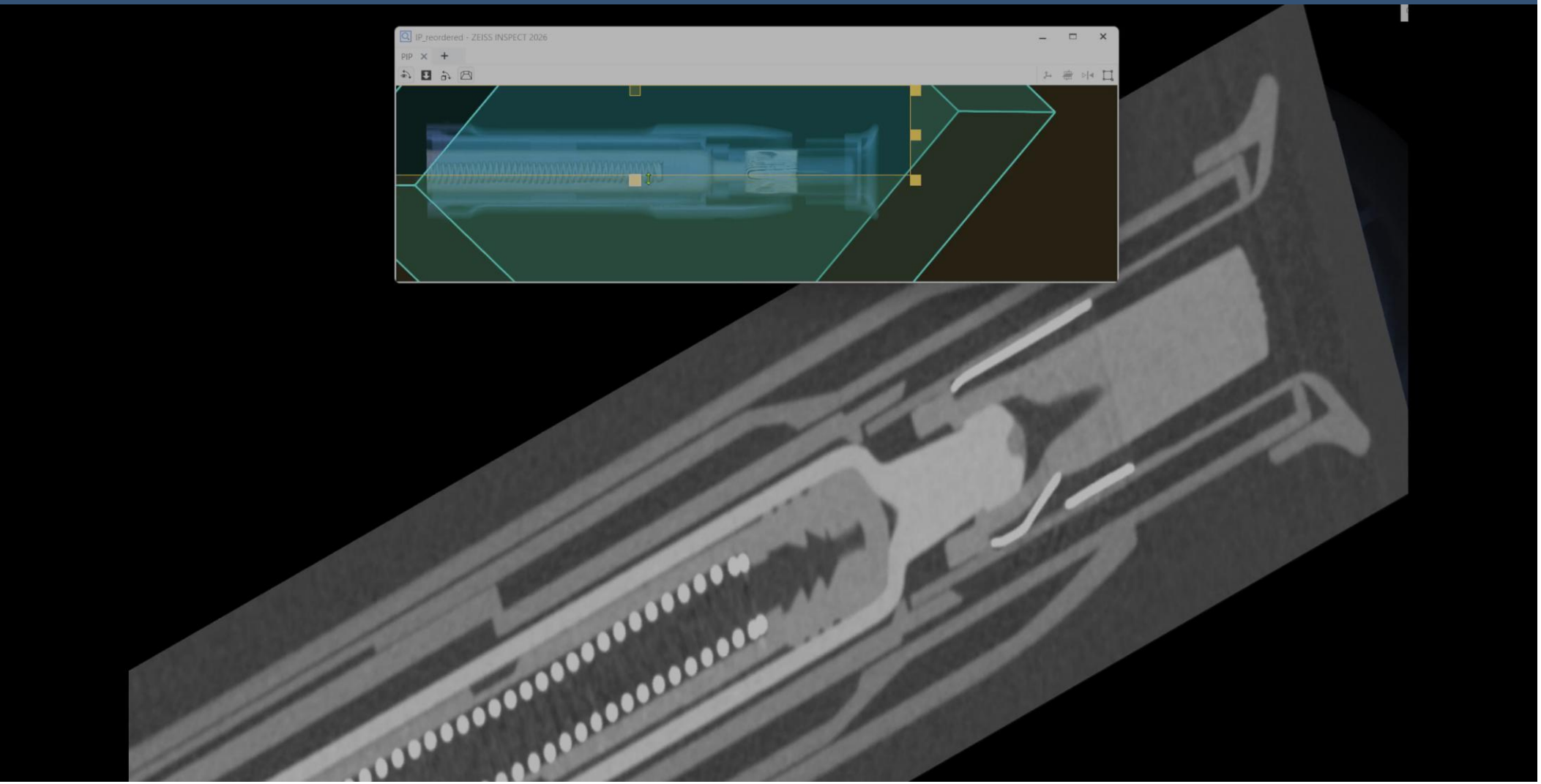
Beyond the Spring: What's Next for TrueSpectrum

Combined VMI+TSx pipeline: Video



Beyond the Spring: What's Next for TrueSpectrum

Combined VMI+TSx pipeline: Video



TrueSpectrum™ on Your Object

Your challenge + TrueSpectrum — let's find out what's possible

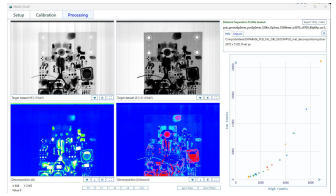
TrueSpectrum™ on Your Object

Your challenge + TrueSpectrum — let's find out what's possible

Have a challenging multi-material object?

3 ways to get started:

1. **Visit us at the booth**
   → Bring your inspection challenge, **talk to the team**



2. **Request a demo dataset**
   → Try TrueSpectrum processing **on your own data**:
   we provide the software and support

3. **Integrate a Varex dual-energy detector**
   → Works with any standard X-ray tube — eg) **THOR-10G**

Contact: jonathan.schock@varexim aging.com | mike.stamm@varexim aging.com

THOR

Q&A

Thank you

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Varex Imaging Deutschland AG, Walluf, Germany

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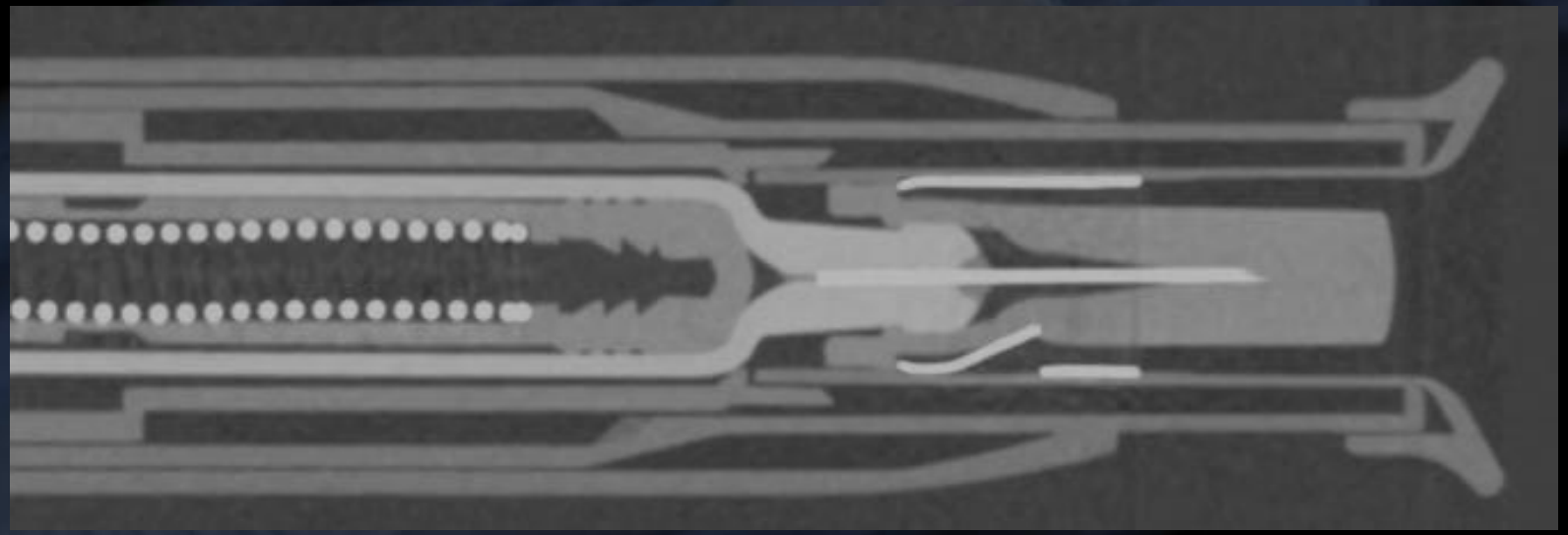
Martin Hu — Varex Imaging, Salt Lake City, USA
Mike Stamm — Varex Imaging International AG, Steinhausen, Switzerland

Contact: jonathan.schock@varexim aging.com | mike.stamm@varexim aging.com



Back deck / bonus slides

Additional Information for the curious

System Setup

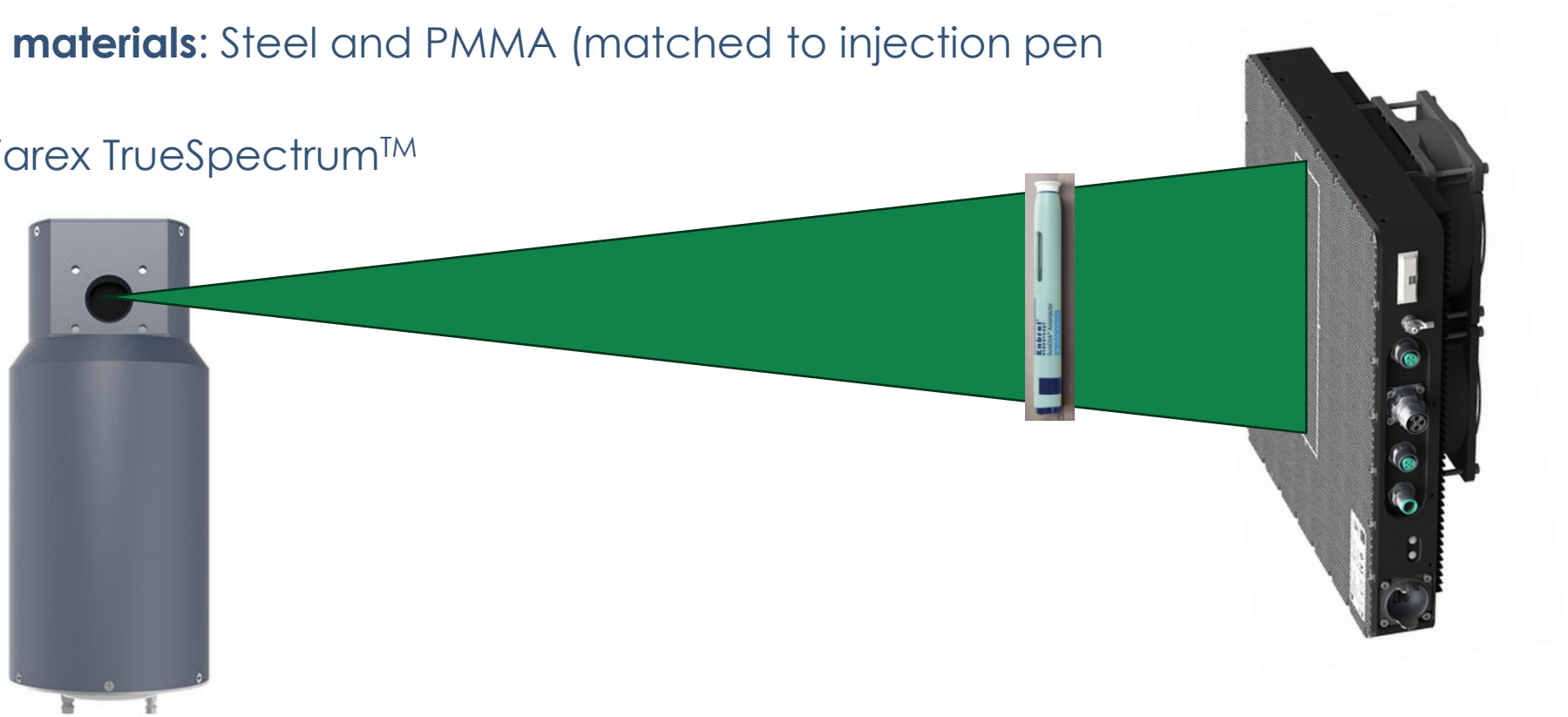
Hardware, software and acquisition parameters

Detector: Varex THOR-10G photon-counting detector
Threshold energies: 55 keV (low bin) and 80 keV (high bin)

Source: 120 kV and 160kV (standard = polychromatic) X-ray tube

Calibration materials: Steel and PMMA (matched to injection pen materials)

Software: Varex TrueSpectrum™



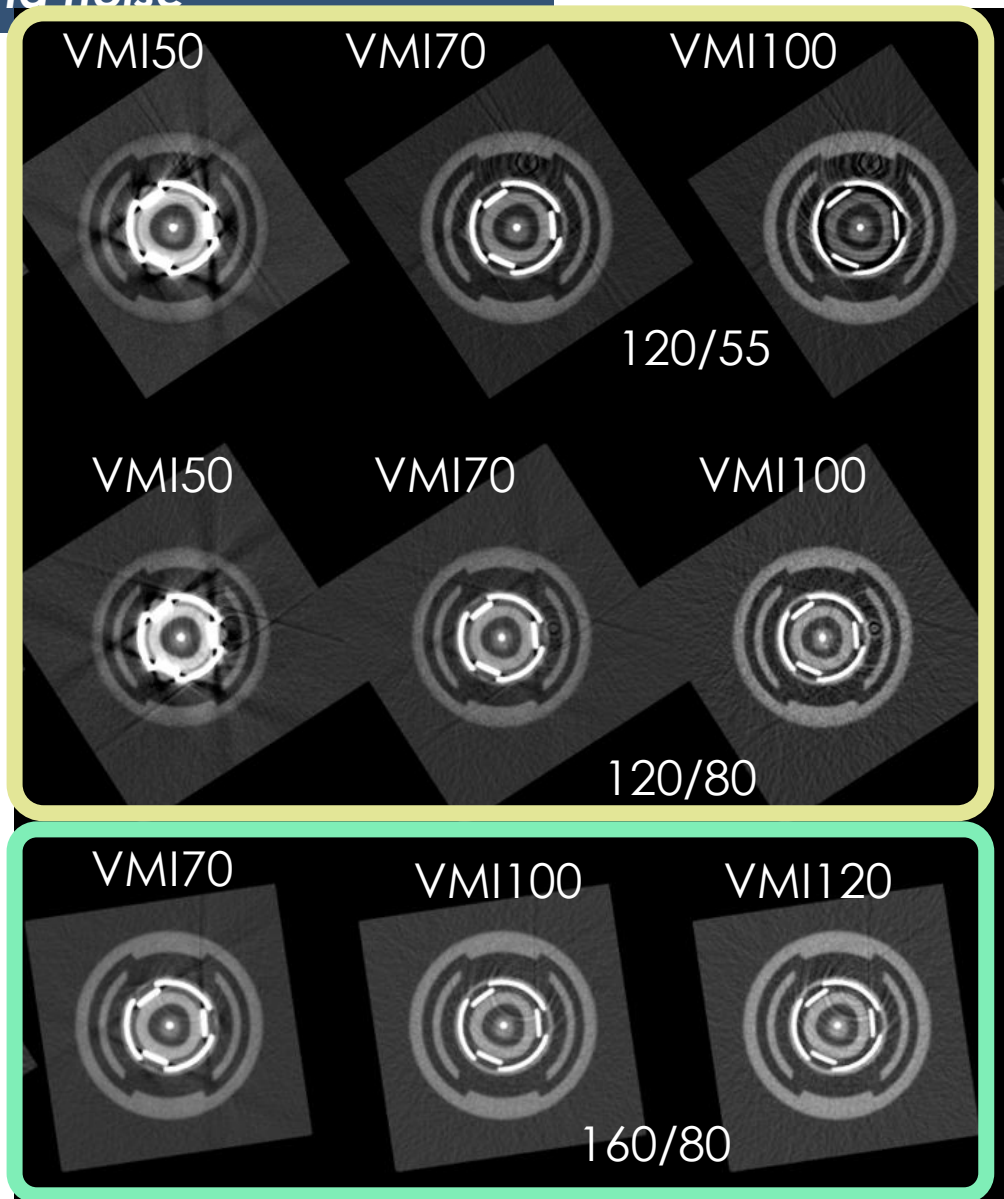
Why 160 kV? Why 80 keV Threshold?

Effect of source energy and threshold on artifact reduction and noise

Why source a 160 kV vs 120 kV?
- → Increases photon penetration through dense steel
- → Allows higher dual energy threshold
- → Results in less pixel ambiguity at spring edges (is it steel or is it plastic?)
- → incorrect labeling introduces artifacts!

Why 80 keV threshold over 55 keV?
- → Higher threshold pushes the HE bin further into the high-energy regime
- → Better spectral separation between LE and HE bins → cleaner decomposition
- → Trade-off: fewer counts in HE bin — noise increases

Why 100 keV VMI? (vs 70keV or 120keV)
- → Sweet spot: sufficient artifact suppression without excessive noise amplification



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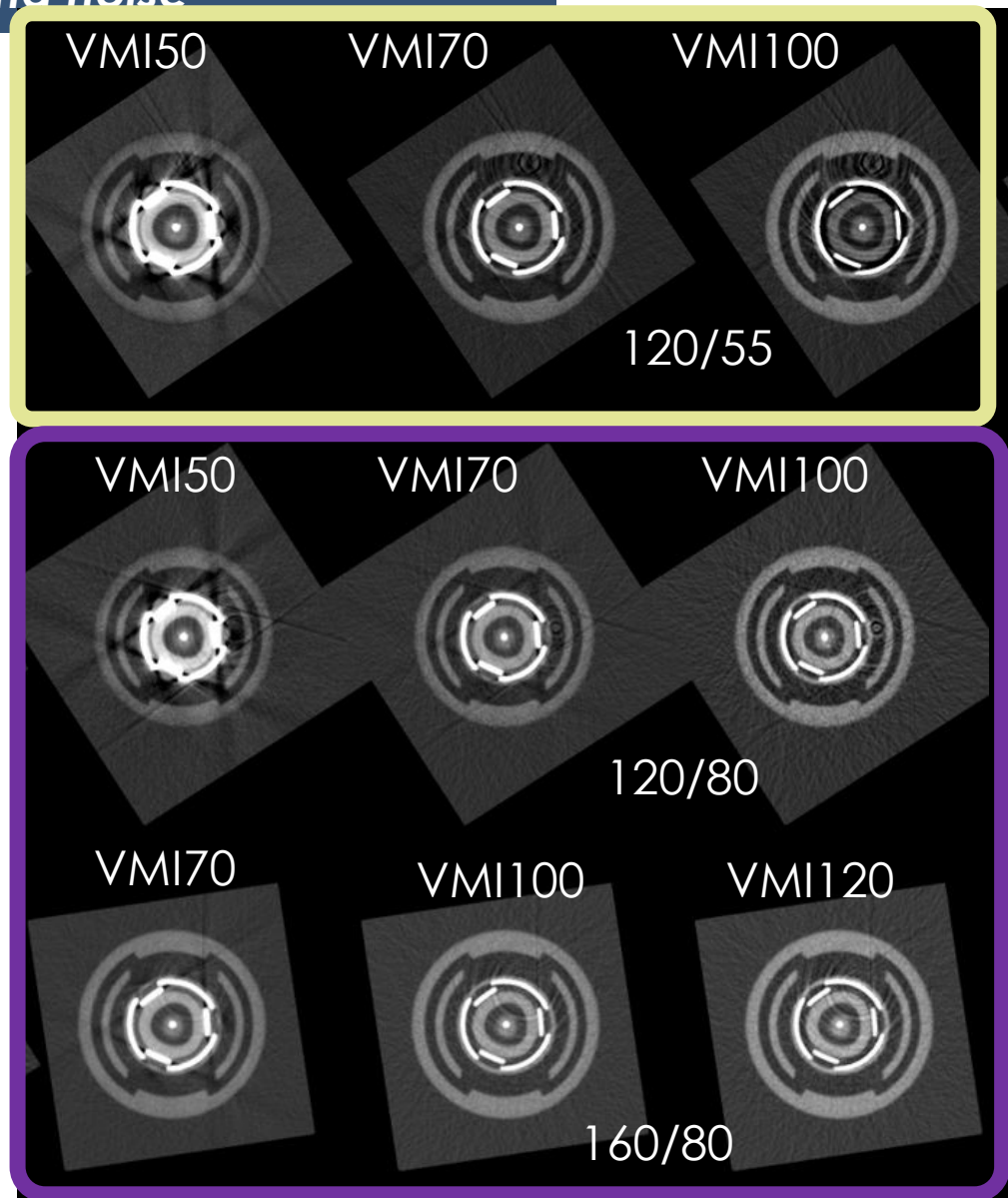

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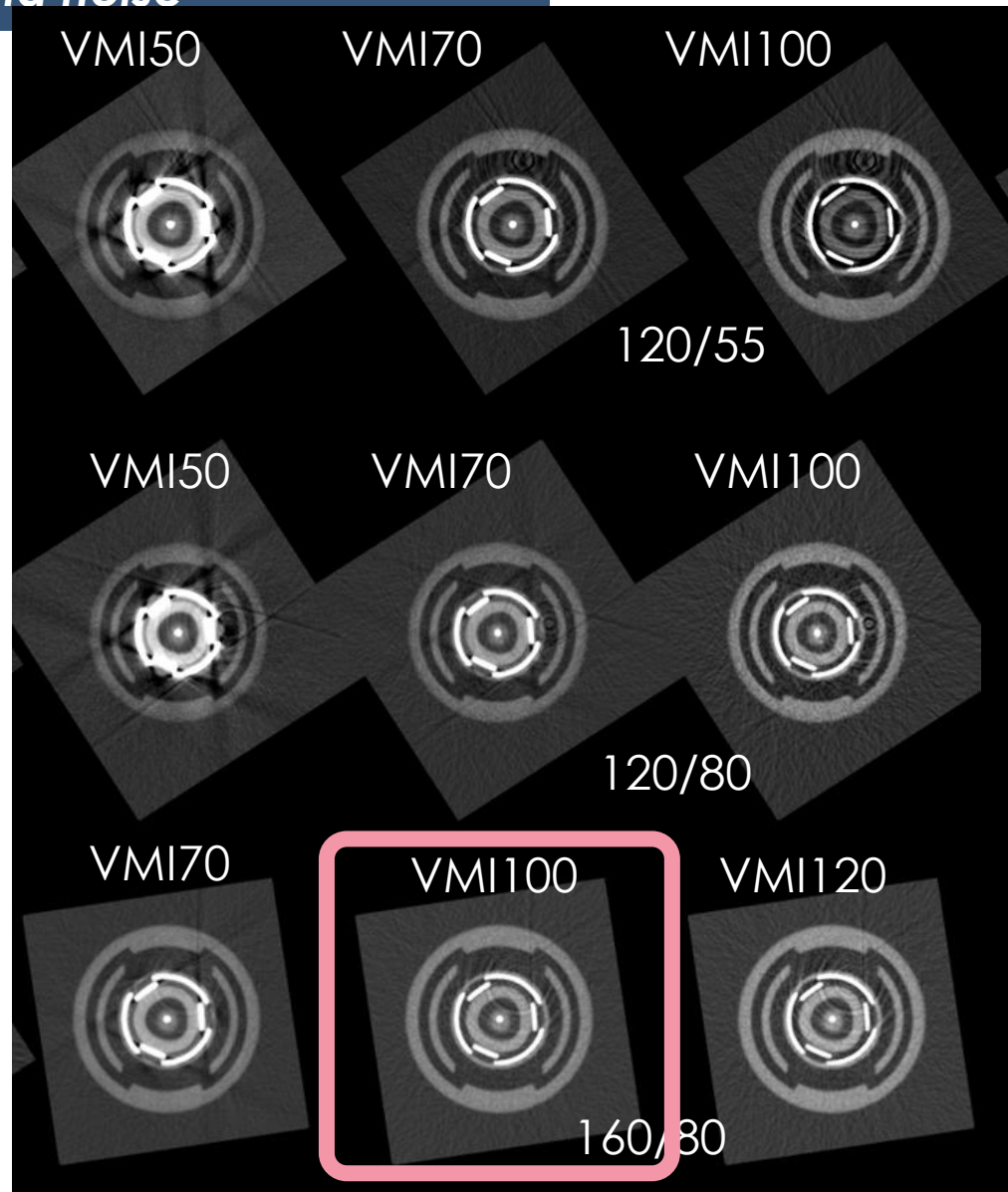


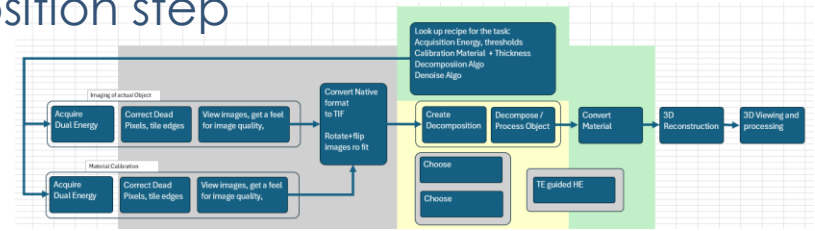
TrueSpectrum: Two Processing Paths

VMI and IGD — same hardware, different pipelines

PATH A — VMI (Virtual Monoenergetic Image)

Acquisition → Material decomposition (EMSAT) → Denoising → VMI → CT reconstruction

→ Requires calibration materials and decomposition step
→ Strength: best interior volume quality (NDT)
→ Software: available now



PATH B — TSx (Trues Spectrum Express)

Acquisition → TSx → CT reconstruction

→ No decomposition, no calibration materials, no VMI step
→ Strength: best exterior surface quality (metrology)
→ Software: available for early adopters