Automatic Target Recognition (ATR) for Cargo

for Special Nuclear Material (SNM)

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Conclusions

- Dual energy is far superior over single energy scanners, due to material discriminating capability via Z_{eff}

- Beam hardening correction and background compensation results in enhancements in performance.
  - Convert all measurements of equivalent thickness of steel
  - Background compensation by in-painting of punctured regions (of suspect SNM)

- Slight mis-alignment of high and low energy measurement can be detrimental to performance

- Parameterizing the same algorithm can be effective in processing data from different scanners

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Overview

- Exploitation of Cargo Advanced Automated Radiographic System (CAARS) Energy Data
  - SAIC Dual Energy Scanner (6/9 MeV Interlaced Pulse-to-Pulse)
  - L-3 Dual Energy Scanner (6/9 MeV Staggered Scanner)
  - Rapiscan Single Energy (6 MeV)
- Devise ATR Algorithms to Detect SNM (high Z material)
  - Dual Energy Processing
  - Image Features
  - Material Discrimination
- Conclusion
  - Superiority of Dual Energy Scanners Over Single Energy Scanner
  - Approaching CAARS goal of over 90% PD and less than 3% PFA.

Ref: J. Medalia, *Detection of Nuclear Weapons and Materials: Science, Technologies, Observations*. Congressional Research Service, p.34, 2009.

ATR for SNM: System Concept

Radiographic Scanner (Single/Dual Energy)

Scanner Information

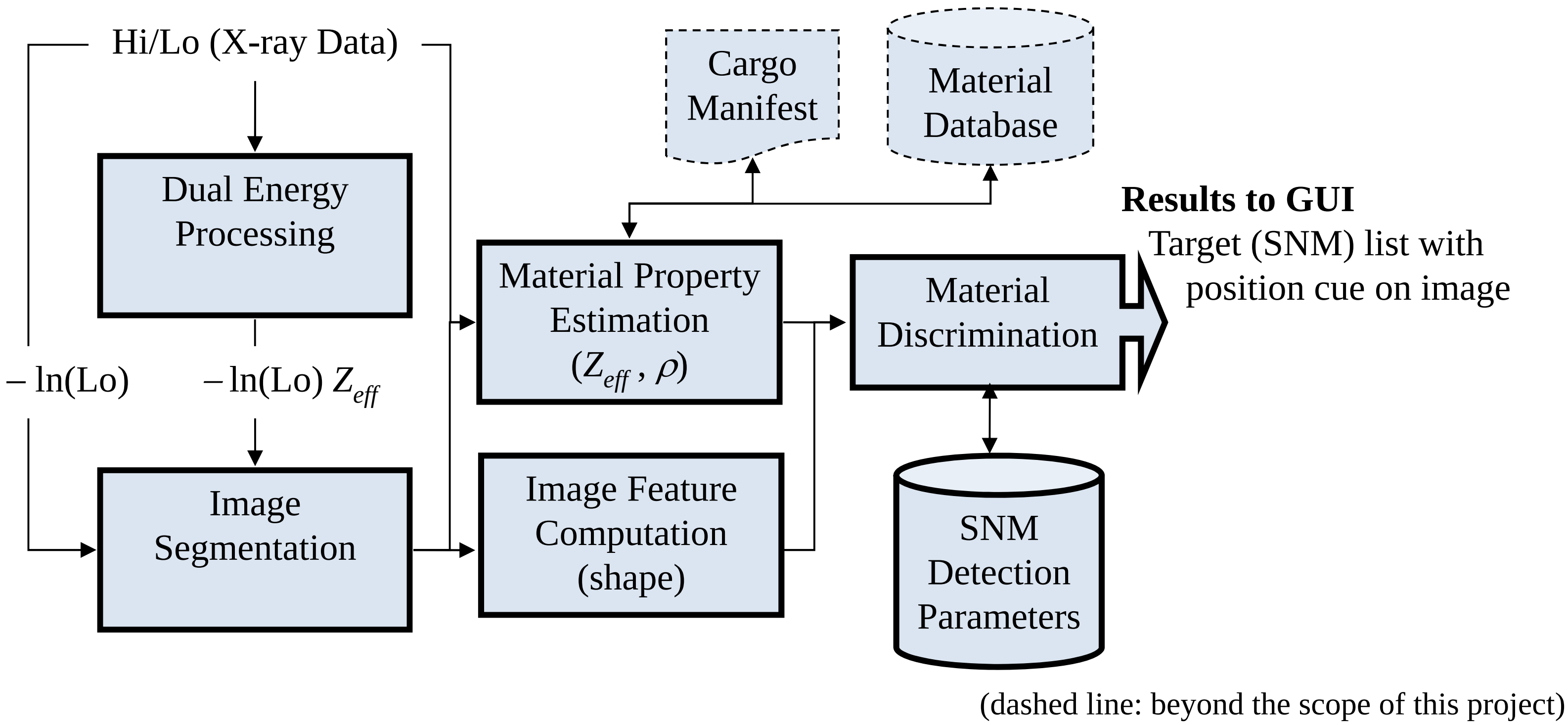
ATR Engine

SNM Detection Parameters

Algorithms

- Dual Energy Processing
- Image Segmentation
- Material Property Estimation
- Image Feature Computation
- Material Discrimination

ATR Engine



Algorithmic Dataflow for ATR Algorithms for SNM Detection.
All blocks are driven by the Scanner Information (e.g., SAIC, L-3 or Rapiscan)

Performance Targets and Goals

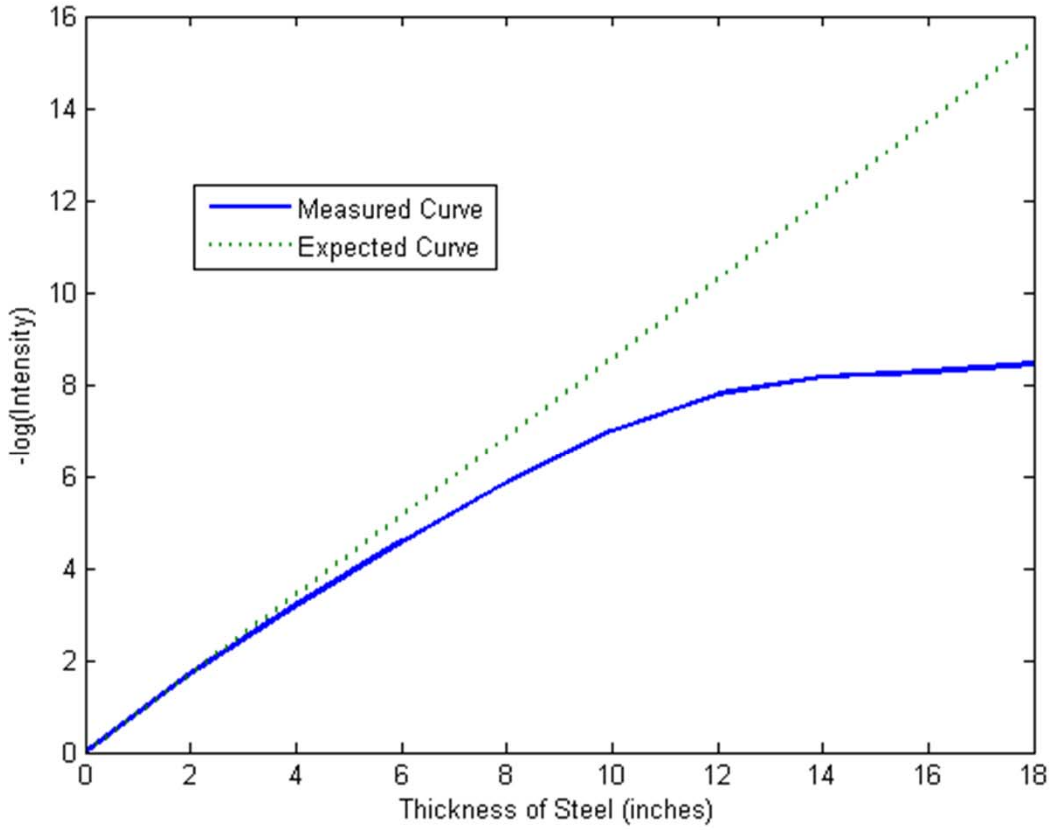
- Performance Targets: Approach CAARS PD/PFA goals
  - ATR must perform “near” CAARS specifications (90%PD, 3%PFA)
  - Operator in-the-loop On-screen Resolution (OSR) expected to push the overall system performance at or beyond CAARS specifications
- Goals Achieved
  - Scanner independent ATR for SNM Detection (driven by Scanner Info)
  - Material property estimation (of effective atomic number Z_{eff} and density ρ)
  - Image feature computation (uses shape information)
  - Material Discrimination by optimum selection of SNM Detection Parameters (tuning the algorithm)
  - Accurate classification of cargo into high and low density and complexity
    - Selection of SNM Detection Parameters based on cargo class (LL, LH, HL, HH)
  - Performance enhancement utilizing beam hardening correction and background compensation

Highlights

- Beam Hardening Correction
- Effective Z Computation
- Background Compensation
- Cargo Classification

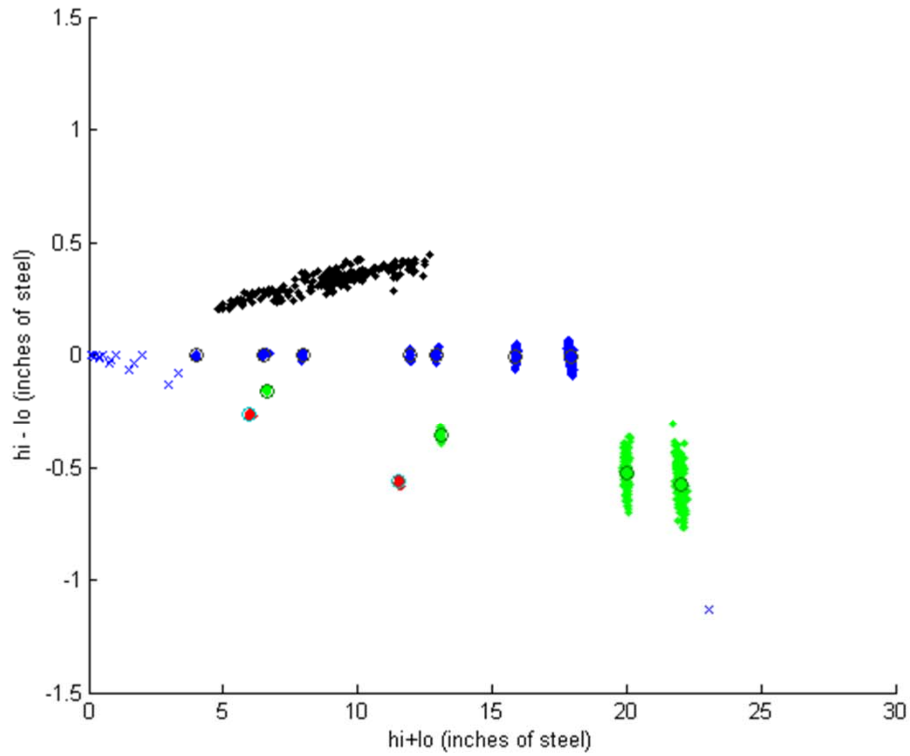
Implementation of Beam Hardening Correction

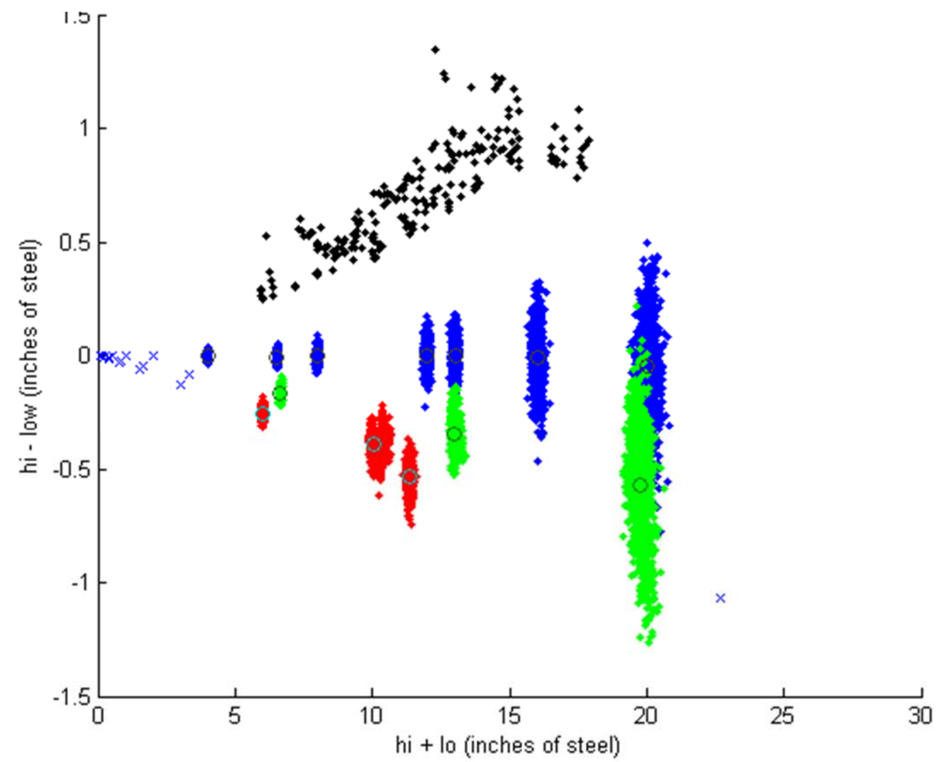
- Beam hardening causes non-linearity in the -log of intensity



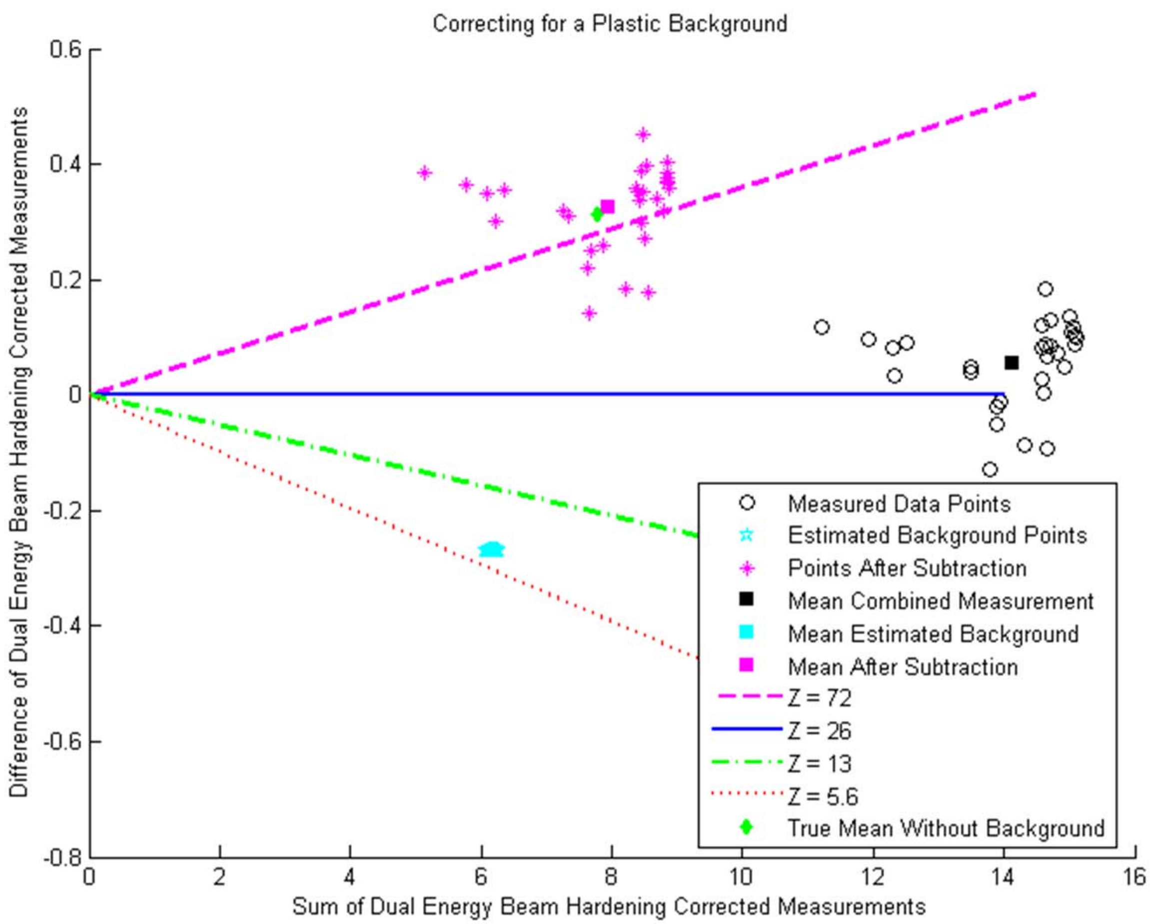
Effective Z Computation

- Construction of calibration curves (Z_{eff} lookup table)



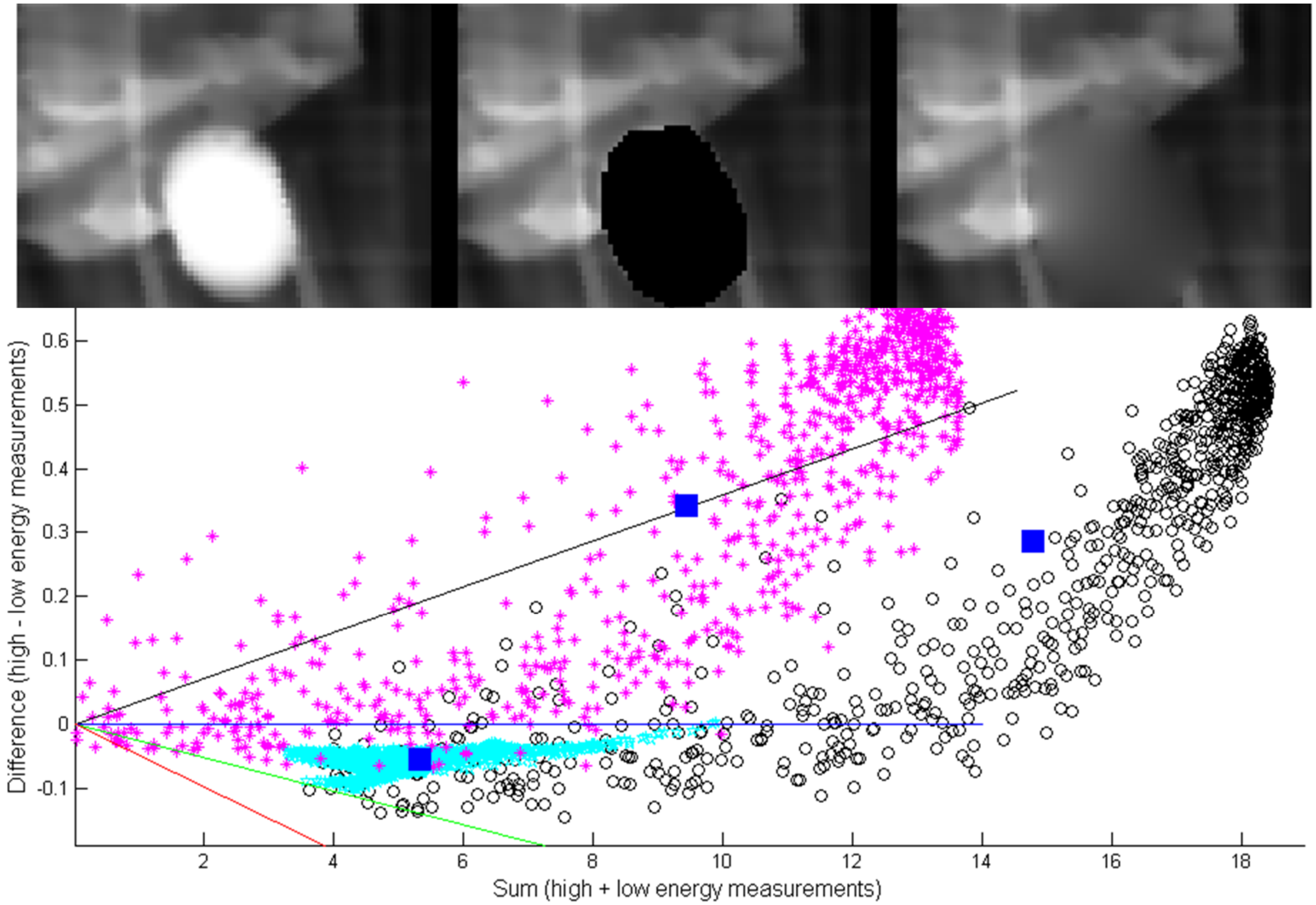


Background Estimation and Subtraction



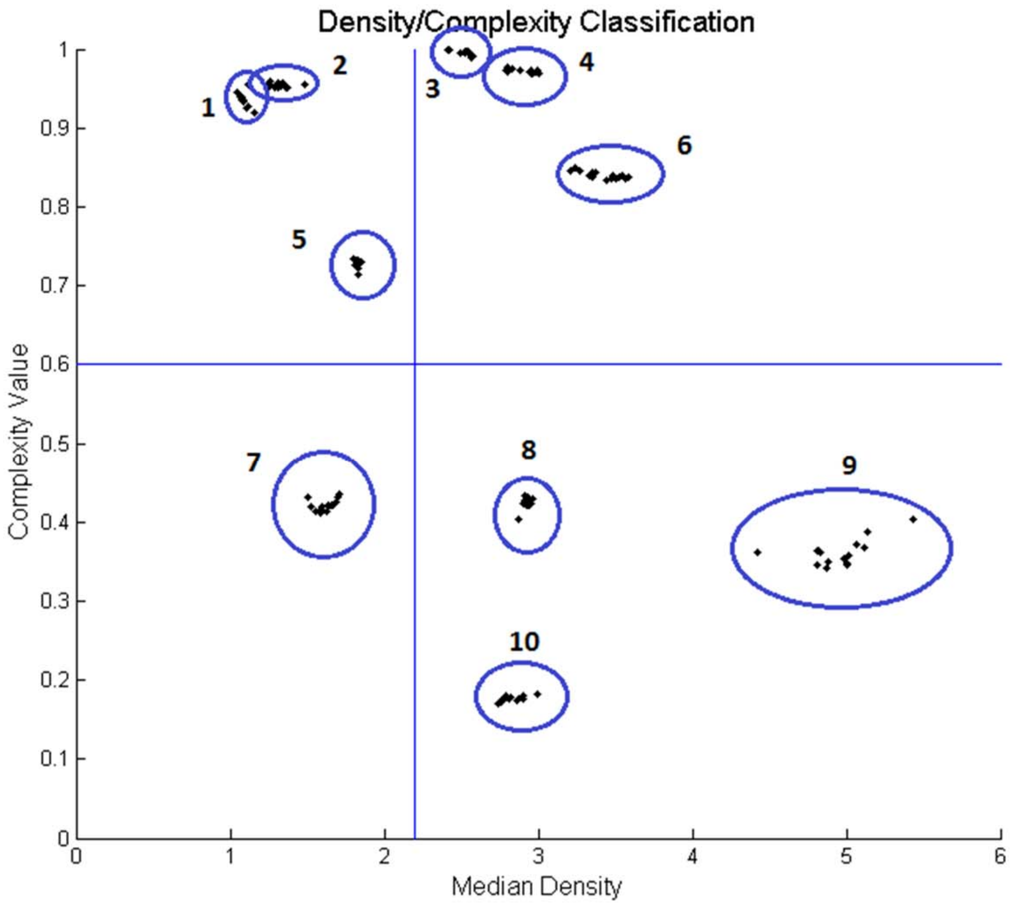
Background is estimated via in-painting and then subtracted before estimating an object's effective atomic number.

Background Compensation Example



Presented at 2012 IEEE SORMA, Oakland, CA, May 14-17.

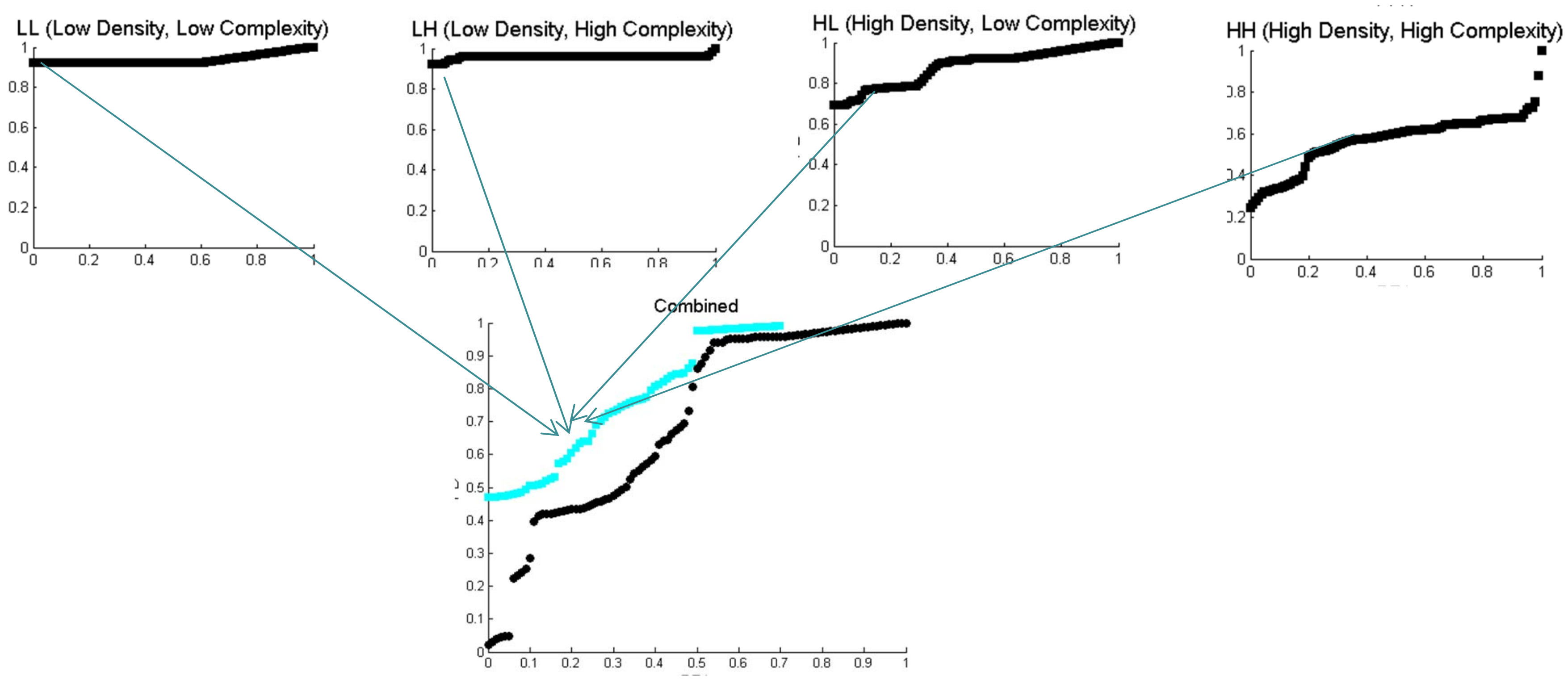
Cargo Classification



1. TVs
2. Tires
3. AC Parts
4. Brake Parts
5. Furniture
6. Buckets
7. T-shirts
8. Water Bottles
9. Cement
10. Wood

Improved Performance via Automatic Cargo Type Classification

- Sample ROC curves at four different cargo types



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Next Steps and Recommendations

- Immediate Next Steps and Recommendations to DNDO
  - Extend ATR to rest of the vehicle (e.g., cab, engine compartment)
  - Develop more cargo classes to enhance ATR performance
  - Scatter estimation and compensation
  - Collaborate with CBP
    - Access to more data, stream of commerce
    - Spend more effort for single energy to be immediately relevant
    - Develop related ATR algorithms for contraband, weapons, etc.
    - Compare ATR detection with cargo manifest
  - Allow access to more data
    - Improved performance due to better tuning of SNM Detection Parameters
- Longer Term …
  - Better lookup tables with scans or more materials/thicknesses
    - Better beam hardening correction and more accurate Z_{eff} estimates
  - Develop a 2-D step wedge scans
    - Potential for more discrimination routines

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