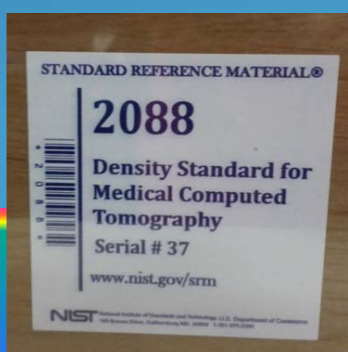
Evaluation of a Lung Density CT Standard Reference Material

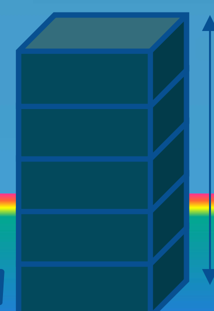
H. Chen-Mayer[1], R. Avila[2], Z. Q. J. Lu[1], Z. Levine[1], and D. Yankelevitz[3]

[1]NIST [2]Accumetra [3]Mt. Sinai Hospital

Development of SRM 2088

- Zachary Levine, Technical champion
- Heather Chen-Mayer, Co-PI
- Brian Zimmerman, CT measurements
- Adam Pintar, statistical analysis
- Dan Sawyer, Dimension metrology
- Michelle O'Brien, x-ray transmission measurements





Motivation

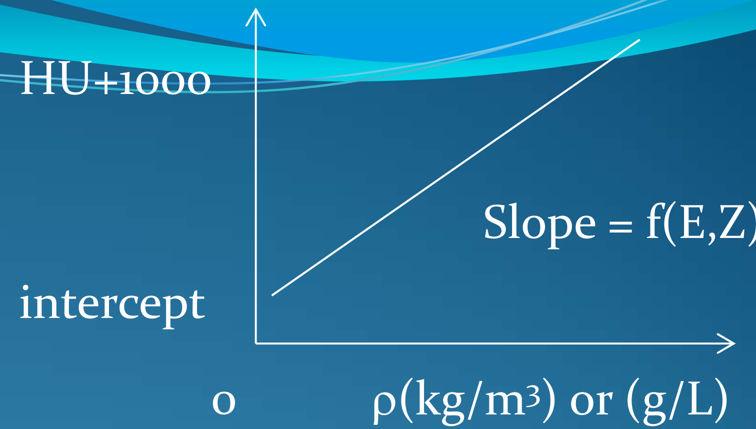
- NIST PET/CT scannerr (Brilliance 16 CT)
- CT quantitative imaging – QIBA/RSNA
- CT volumetric (length scale) vs density (intensity)
- COPD (Chronic obstructive pulmonary disease) progression and monitoring
- Repeat measure – accuracy and precision
- Smallest Real Change – within subject variance – what is the intrinsic noise level given a current (dose)
- CT parameters (current, reconstruction slice thickness)
- Standard Reference for CT density – scanner calibration, accuracy and precision

$$HU = \frac{\mu - \mu_w}{\mu_w} 1000 \begin{cases} \text{Air } -1000 \text{ HU} \\ \text{Water } 0 \text{ HU} \end{cases}$$

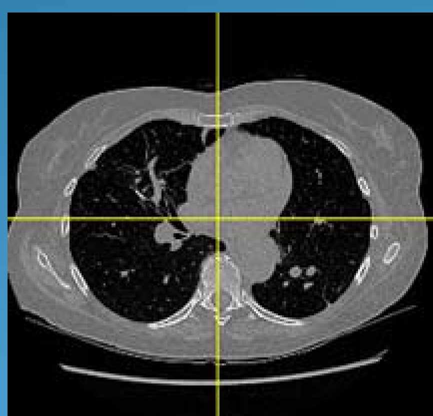
$$\mu = \int w(E)\mu(E)dE$$

$$\mu(E, \rho, Z) = \alpha\rho \frac{Z^k}{E^l} + \beta\rho$$

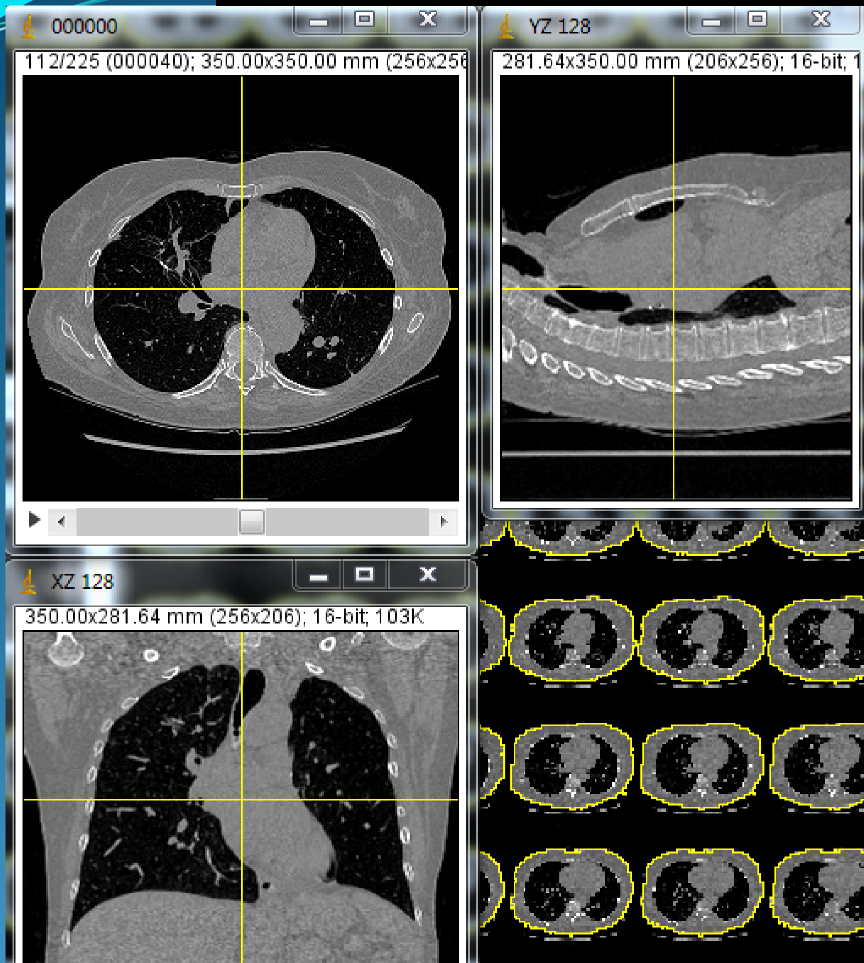
$$HU + 1000 = \frac{\mu}{\mu_w} = f(E, Z)\rho$$

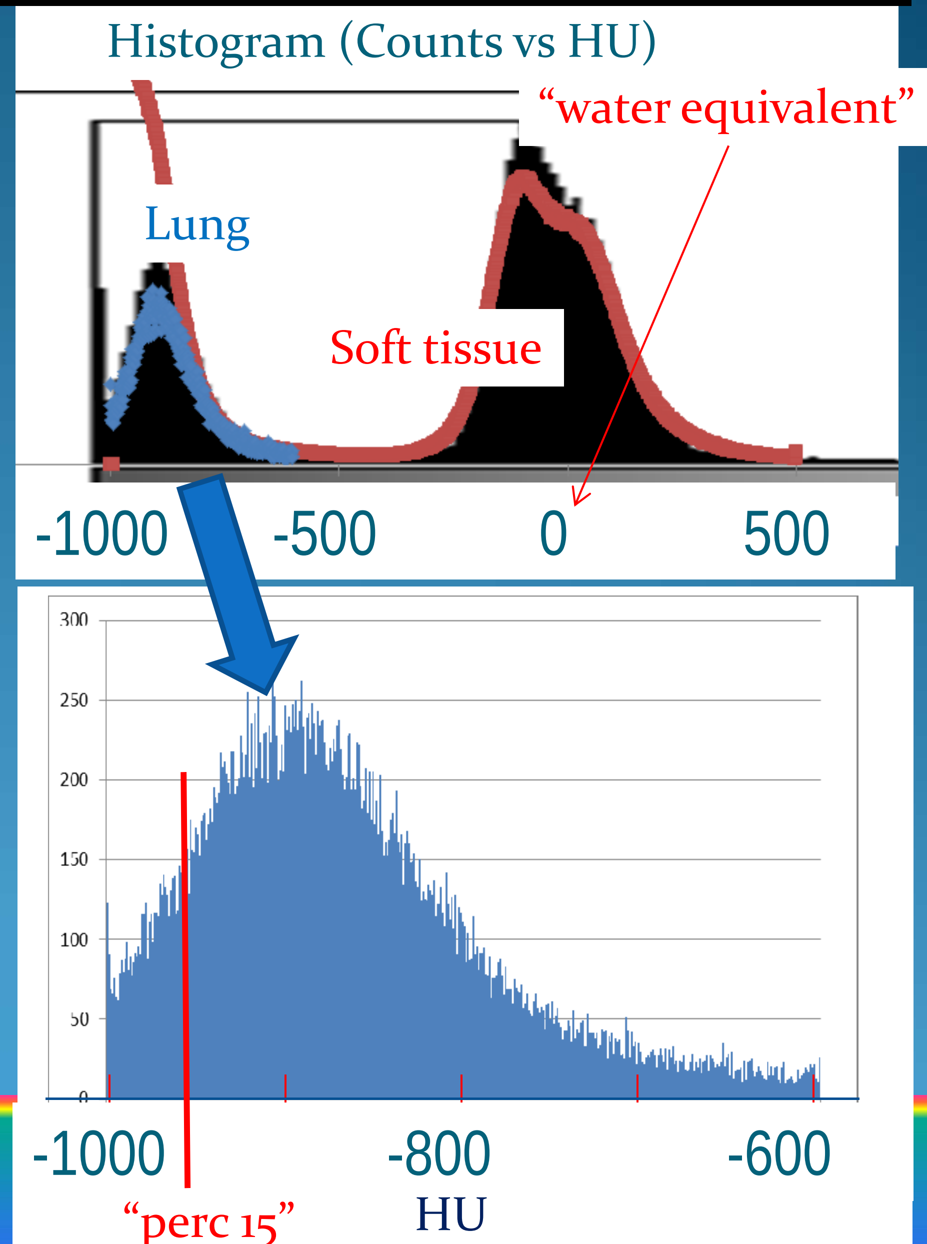


F(E,Z) depends on material and scanner spectrum, need dual-energy method to decode – separate work



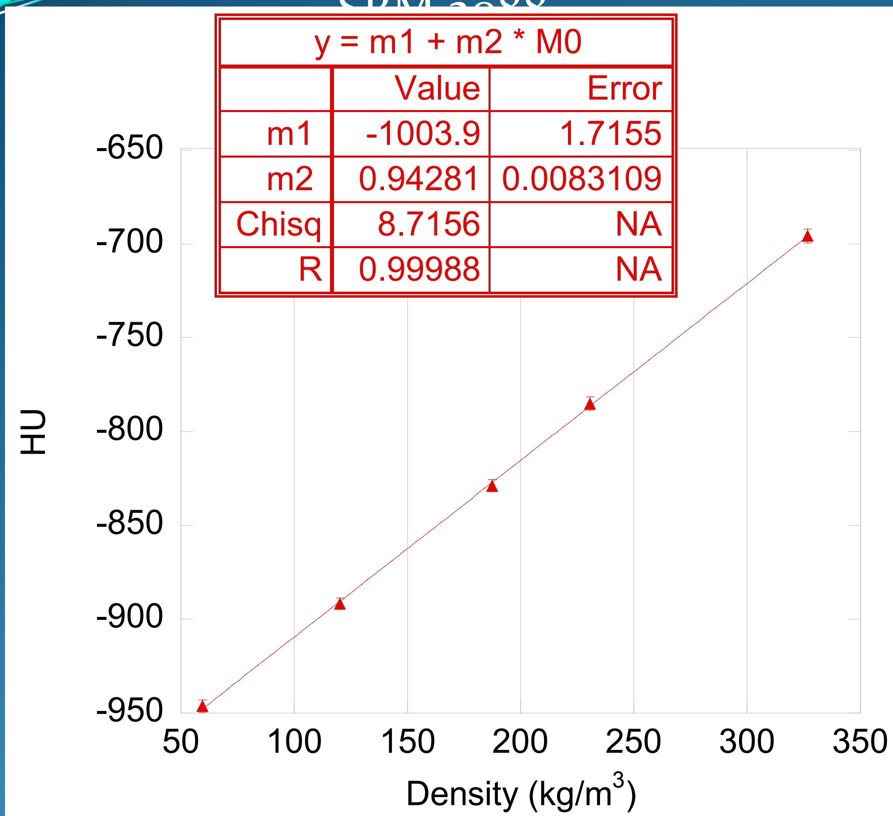
Real lung data (Public Image Archive)



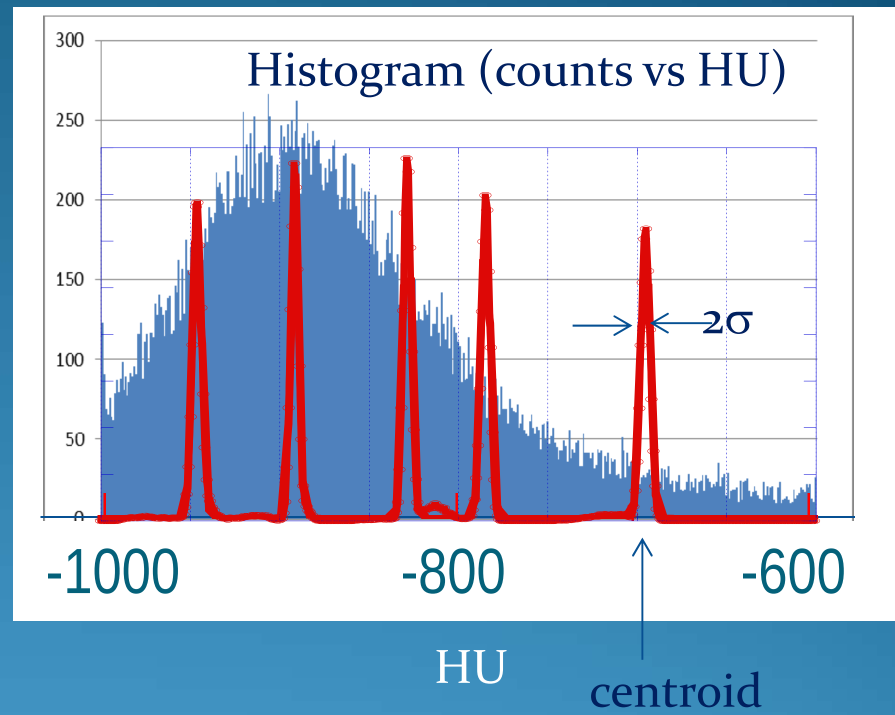


50 yr male lung capacity -40 mL/yr
1% of full lung 4 L
MLD -850 HU, or 150 g/L
1% -> 1.5 g/L, or 1.5 HU

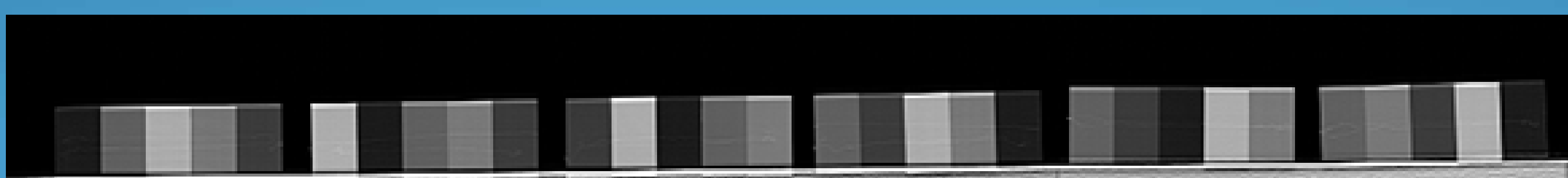
$$f(x) = B + A \sum \exp\left(-\frac{(x - x0)^2}{2\sigma^2}\right)$$



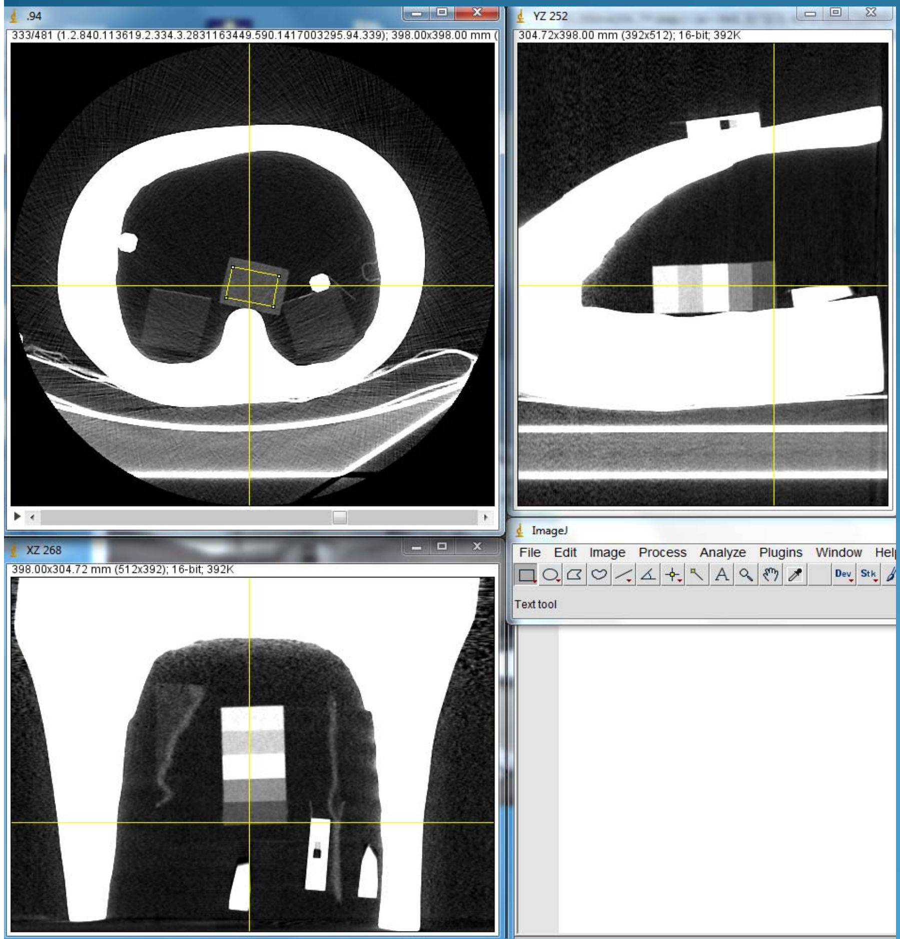
y = m1 + m2 * M0		
	Value	Error
m1	-1003.9	1.7155
m2	0.94281	0.0083109
Chisq	8.7156	NA
R	0.99988	NA

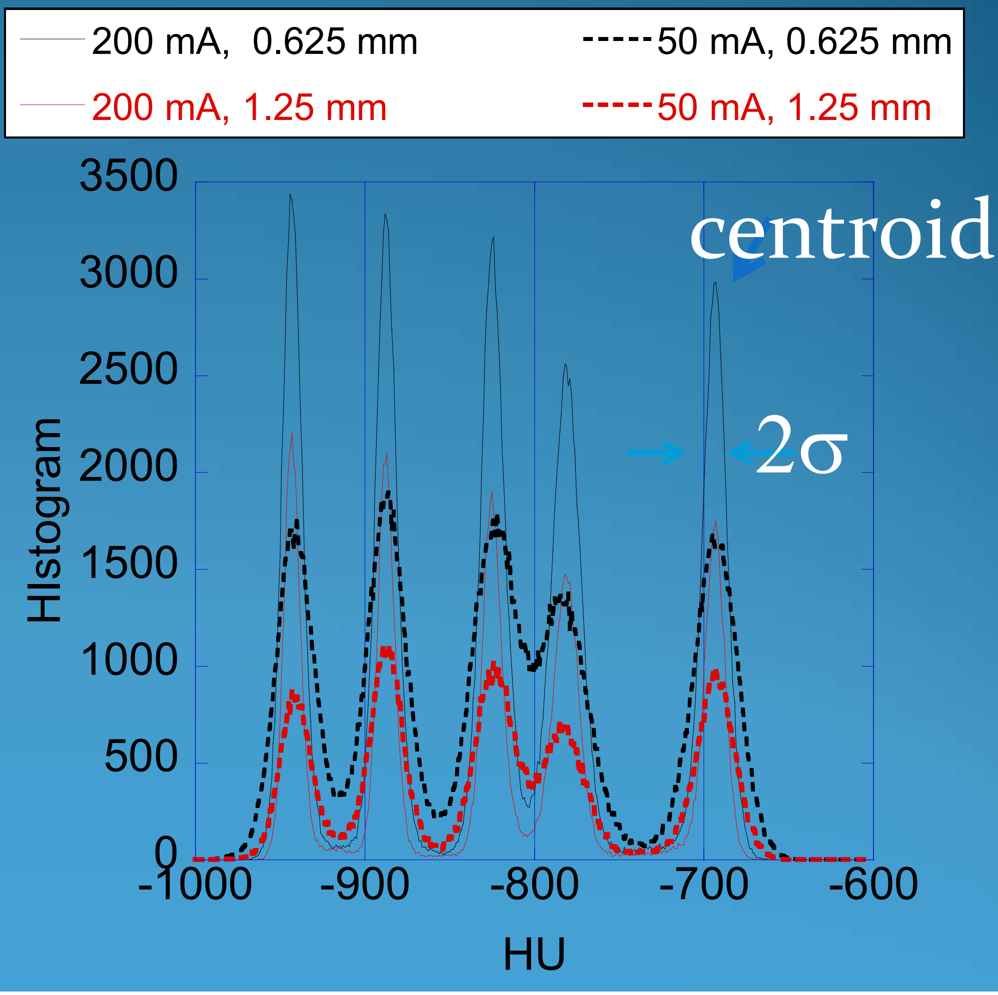


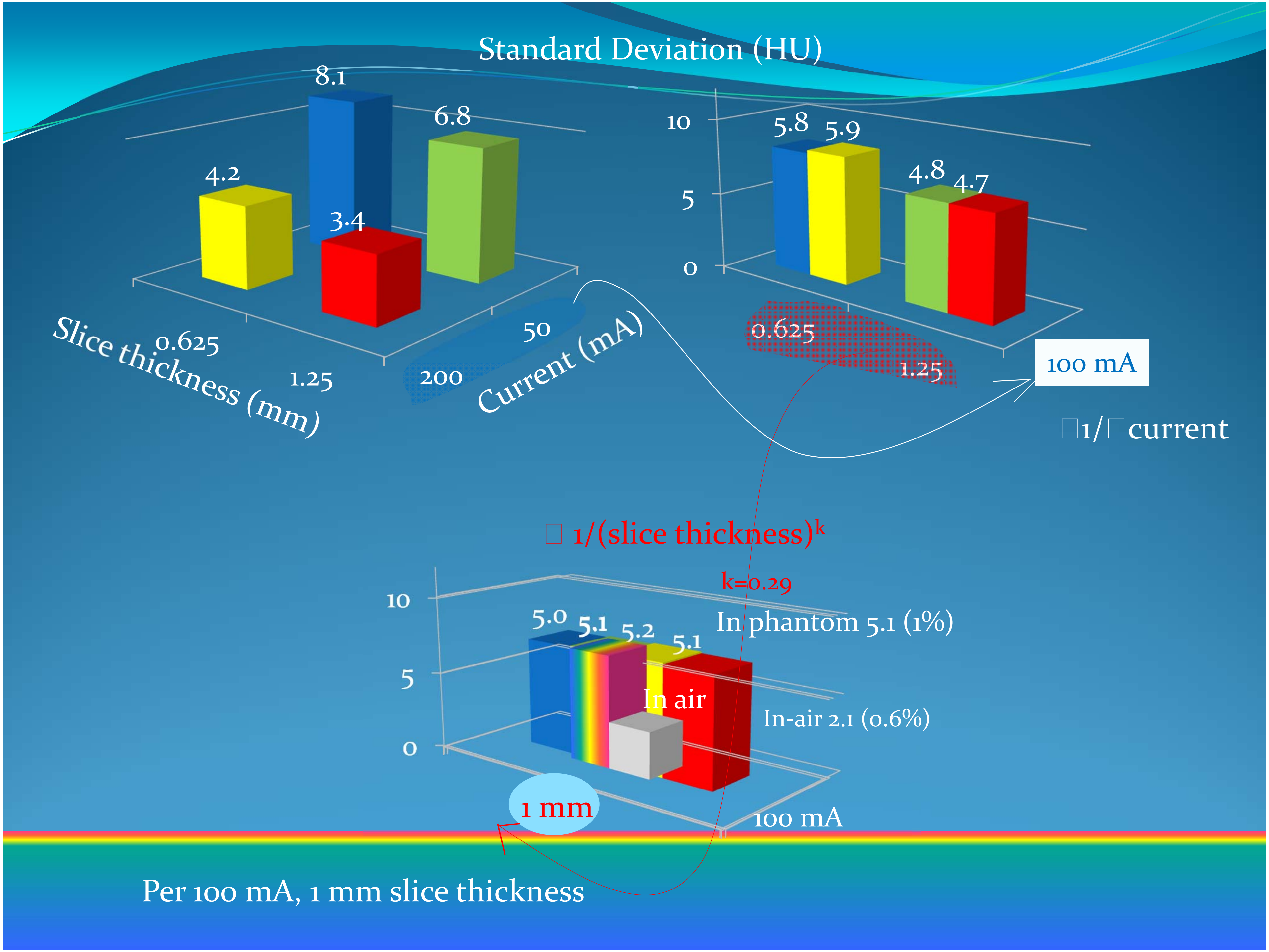
Slope □0.95 HU/(kg/m^3)

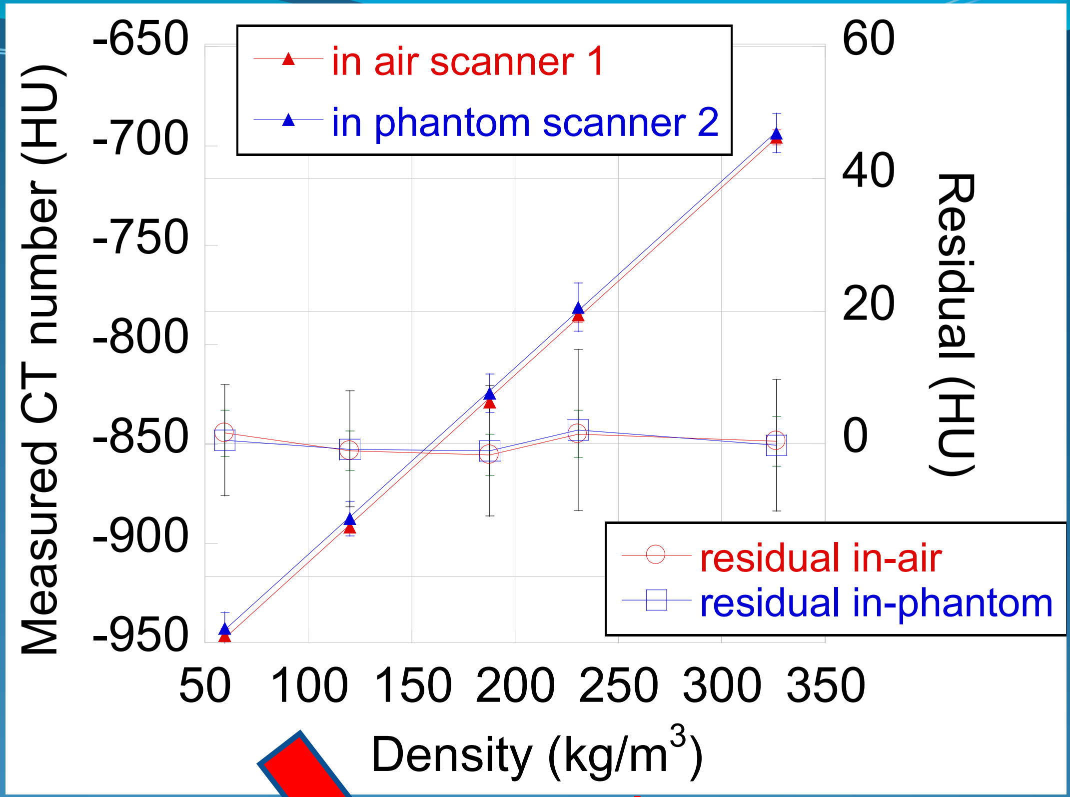


Clinical 64-row scanner
Varying scanning protocol:
Tube current: 50 mA, 200 mA
Reconstruction slice thickness: 0.625 mm, 1.25 mm





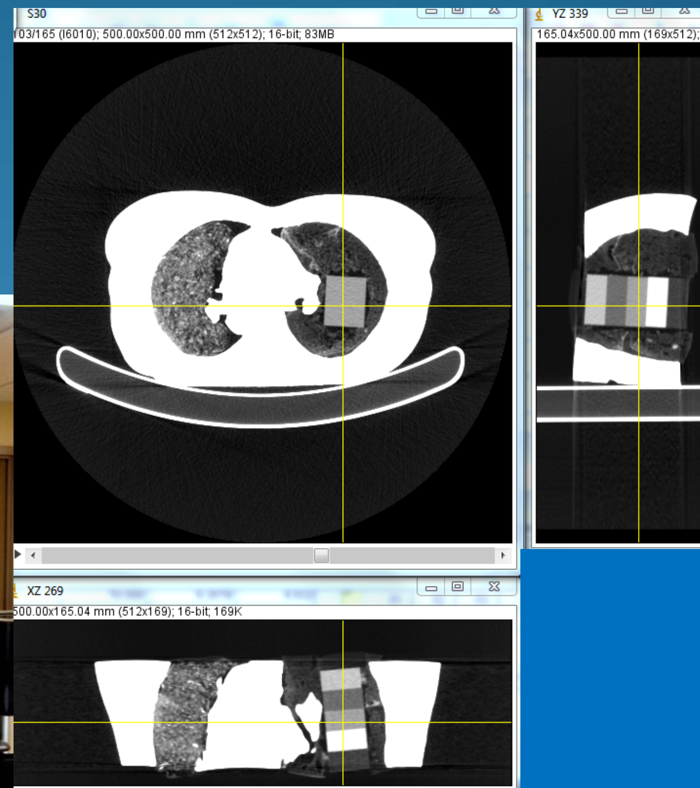

Standard Deviation (HU)
8.1
6.8
4.2
3.4
Slice thickness (mm)
0.625
1.25
50
200
Current (mA)
10
5
0
5.8
5.9
4.8
4.7
0.625
1.25
100 mA
□1/□current
□ 1/(slice thickness)^k
k=0.29
10
5
0
5.0
5.1
5.2
5.1
In phantom 5.1 (1%)
In air
In-air 2.1 (0.6%)
1 mm
100 mA
Per 100 mA, 1 mm slice thickness



Parameters from weighted linear fit	Unit A		Unit B	
	In-air scanner 1	In-phantom* scanner 1	In-air scanner 1	In-phantom scanner 2
slope	0.946 (0.010)	0.950 (0.012)	0.943 (0.009)	0.936 (0.006)
intercept	-1002.7 (2.0)	-1002.3 (2.4)	-1004.1 (1.8)	-999.3 (1.2)
r	0.9997	0.9995	0.9997	0.9999

***Different form the Sinai phantom – the NIST one is a 3D printed anthropomorphic phantom shown in photo below**

Parallel work: SRM foam inside a 3D printed anthropomorphic phantom



Dr. Matt Mille
NIST NRC Postdoc

Miss Lauren Cronise
Summer intern 2014

Dr. Peter Liacouras
3D Medical Application Center
Walter Reed Hospital

Summary

- Lung density SRM measured in air and in phantom
- Effects of dose and reconstruction thickness on standard deviation of distribution of the HU value
  - Dose effect– follow normal statistics
  - Thickness effect – does not follow normal statistics – pixel correlation, need modeling
- In-air and in-phantom measurements – attenuation increases standard deviation but does not change mean value
- Future plans: better experimental design and rigorous statistical analysis
- Building realistic lung phantoms