Elettra Sincrotrone Trieste

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# A method for the quantitative discrimination of breast tissue chemical composition based on the spectral decomposition of X-ray tomographic breast images

The 106th National Congress of the Italian physical Society

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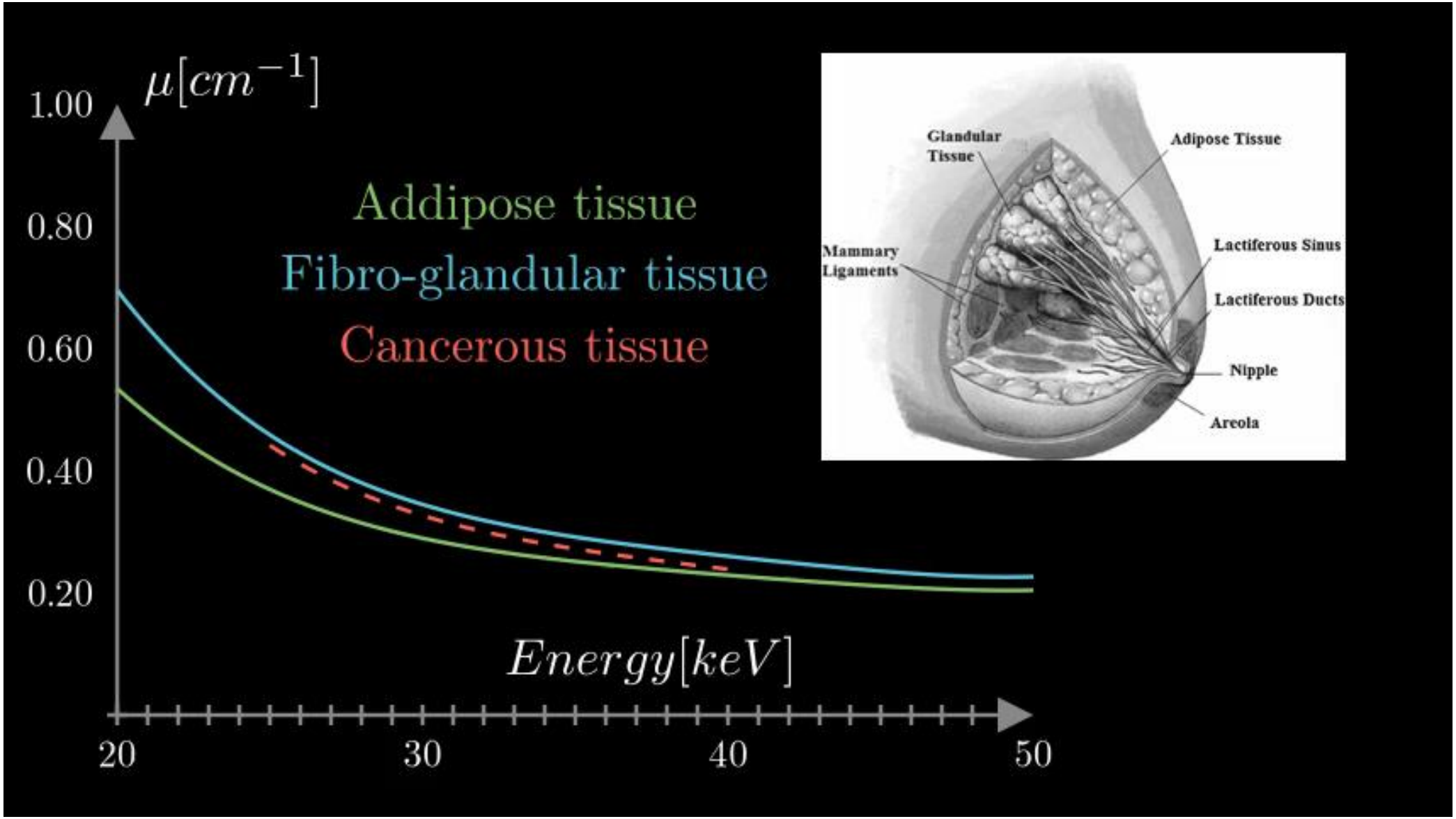
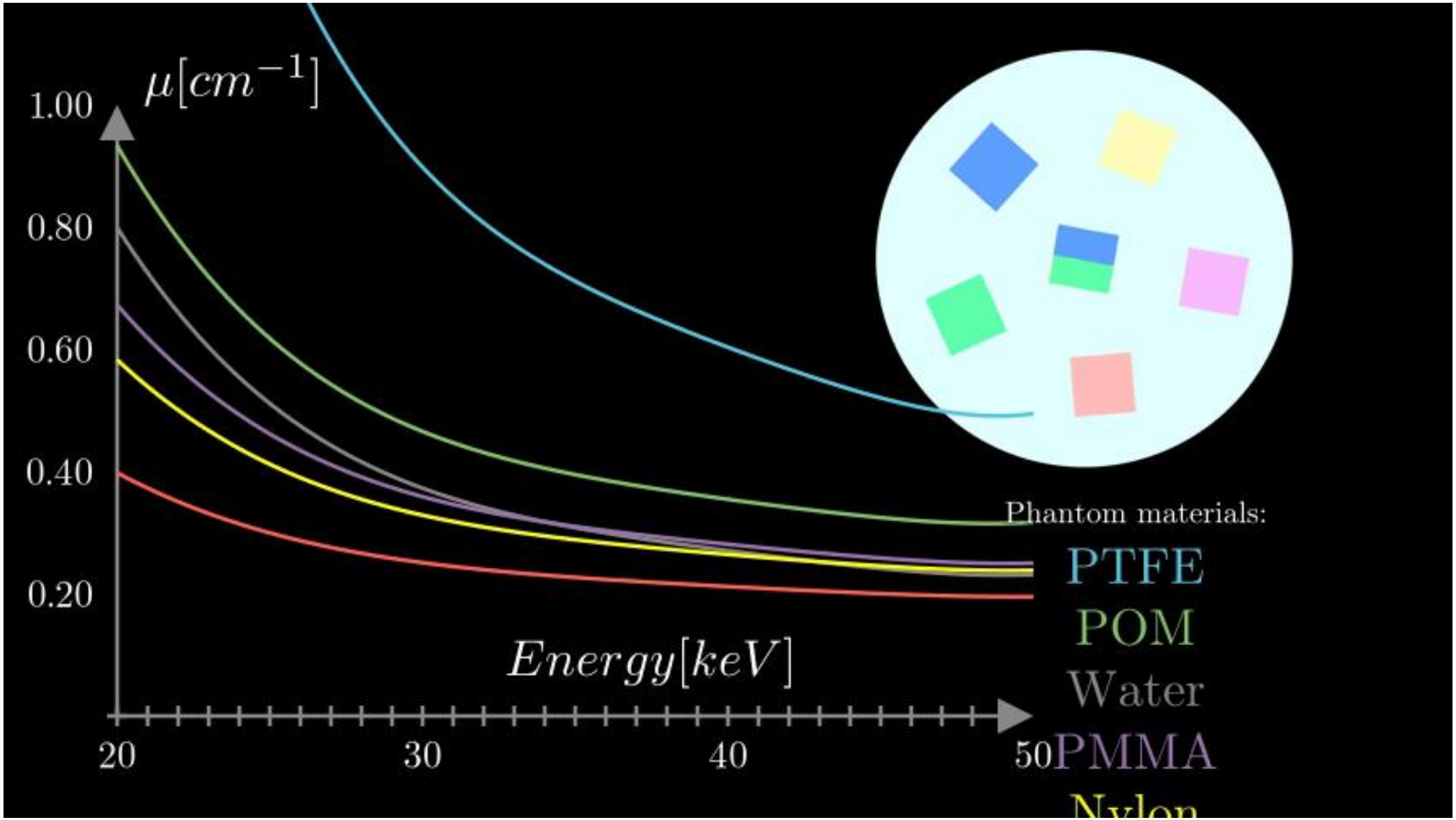
# Synchrotron radiation breast CT

Beam characteristics:

1. Monochromatic
2. Spatial coherence
3. High photon flux


$\mu[cm^{-1}]$
1.00
0.80
0.60
0.40
0.20
Addipose tissue
Fibro-glandular tissue
Cancerous tissue
$Energy[keV]$
20
30
40
50
Glandular Tissue
Adipose Tissue
Mammary Ligaments
Lactiferous Sinus
Lactiferous Ducts
Nipple
Areola

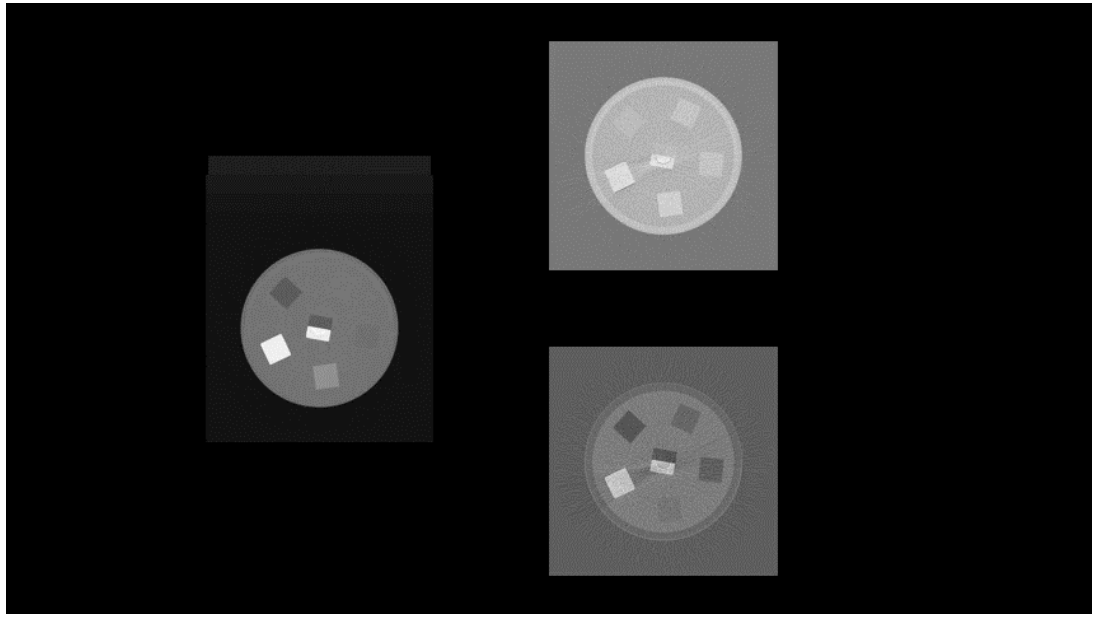

$\mu[cm^{-1}]$
1.00
0.80
0.60
0.40
0.20
$Energy[keV]$
20
30
40
50
Phantom materials:
PTFE
POM
Water
PMMA
Nylon

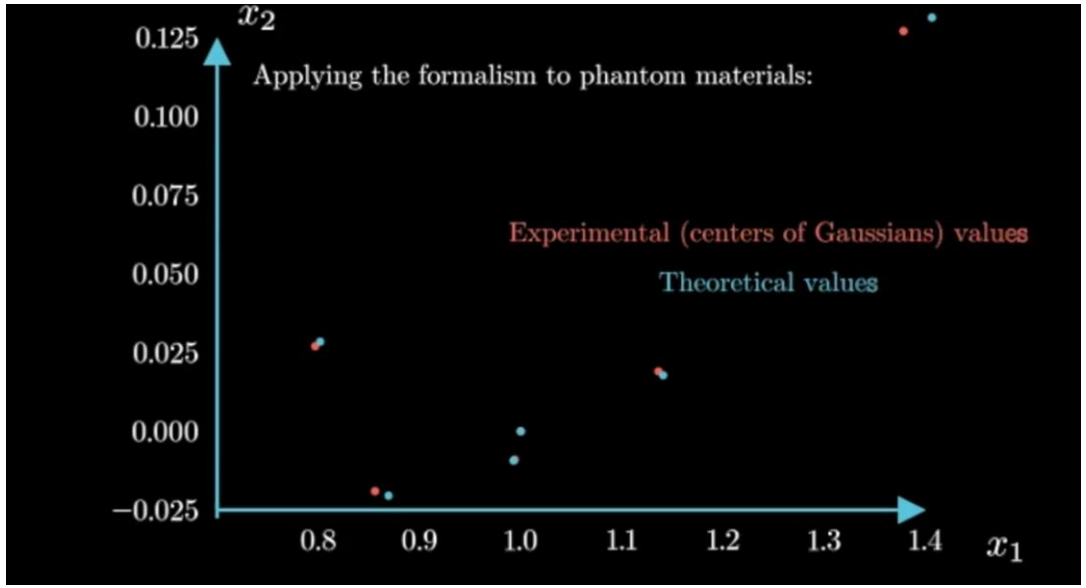
## Theoretical derivation

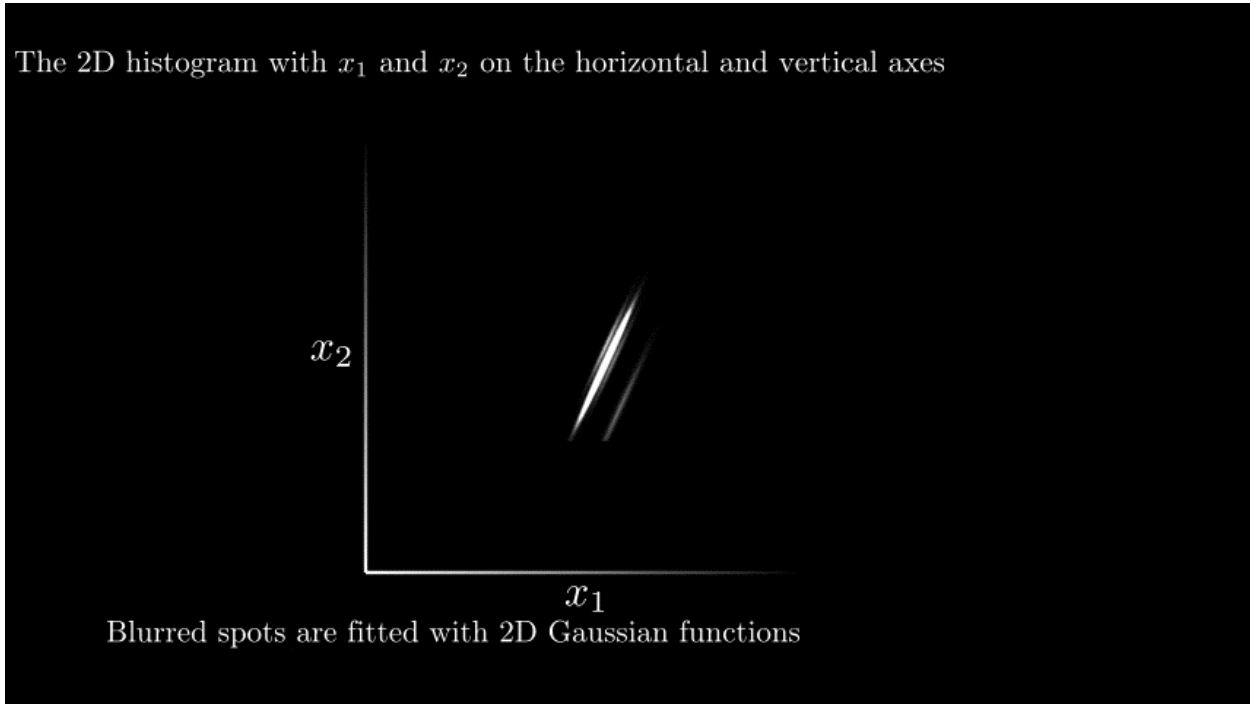
$$\mu(E,\rho,Z,A) = \frac{\rho Z^n}{A f_p} + \frac{\rho Z}{A f_c} \quad \mu(E) = x_1 \mu_{PMMA} + x_2 \mu_{Al}$$

Applying the definition of $\mu$ to each basis material
and then solving in terms of $f_p$ and $f_c$

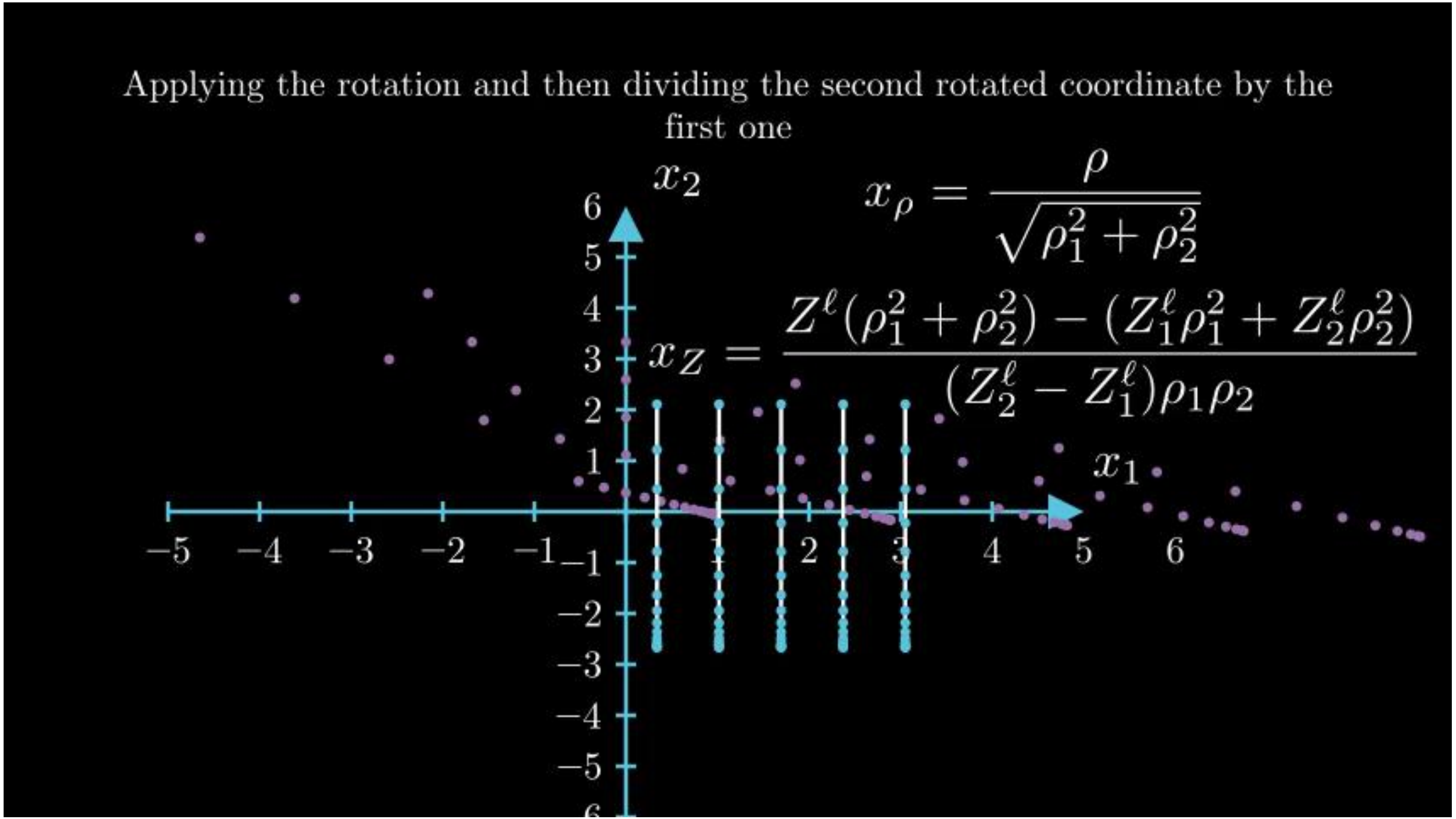
$$x_1 = \frac{\rho Z_1 (Z^n Z_2 - Z Z_2^n)}{\rho_1 Z (Z_1^n Z_2 - Z_1 Z_2^n)} \quad x_2 = \frac{\rho Z_2 (Z Z_1^n - Z^n Z_1)}{\rho_2 Z (Z_1^n Z_2 - Z_1 Z_2^n)}$$

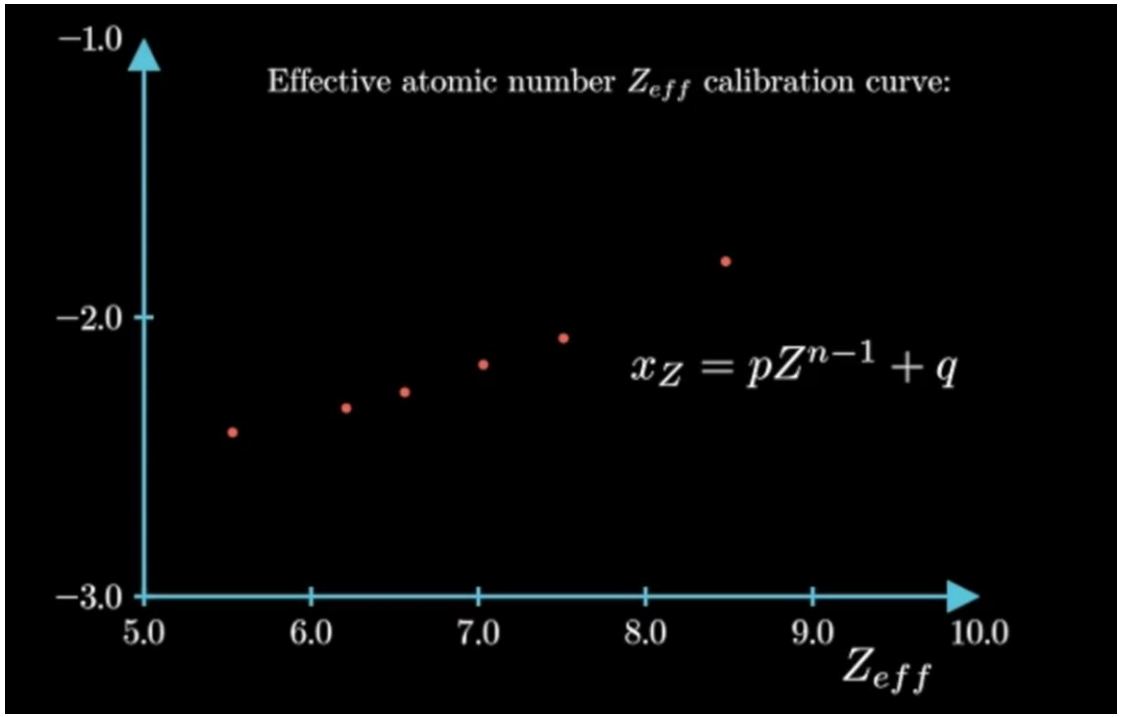


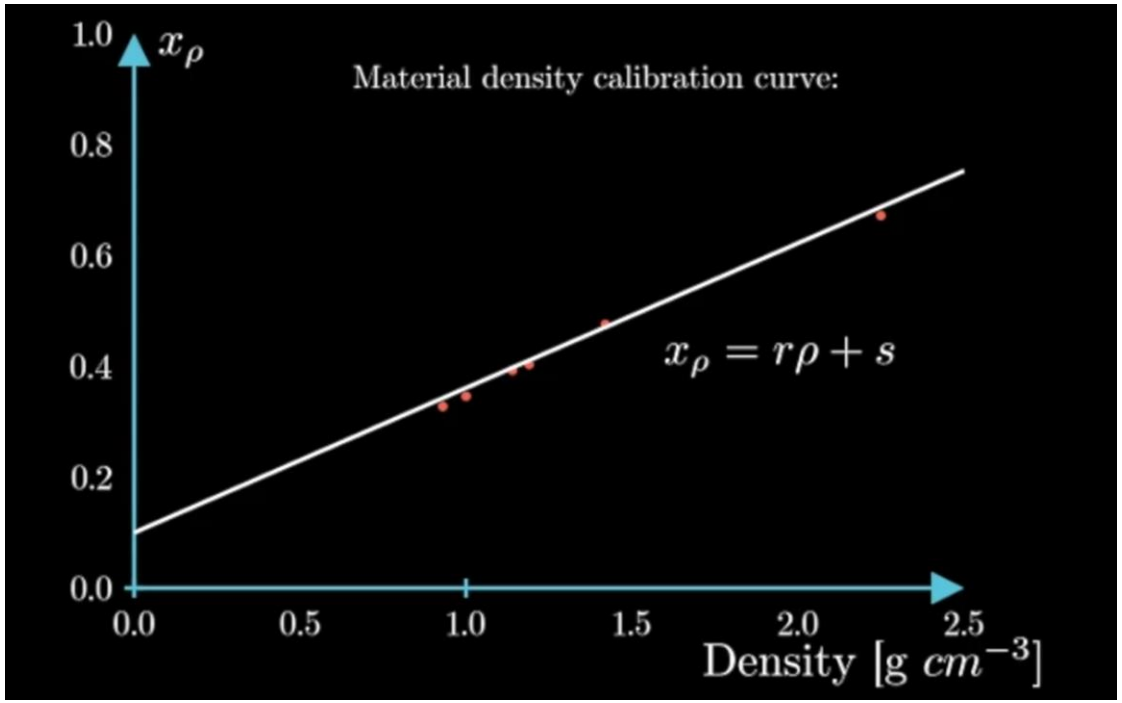

$x_2$
0.125
0.100
0.075
0.050
0.025
0.000
−0.025
Applying the formalism to phantom materials:
Experimental (centers of Gaussians) values
Theoretical values
0.8
0.9
1.0
1.1
1.2
1.3
1.4
$x_1$

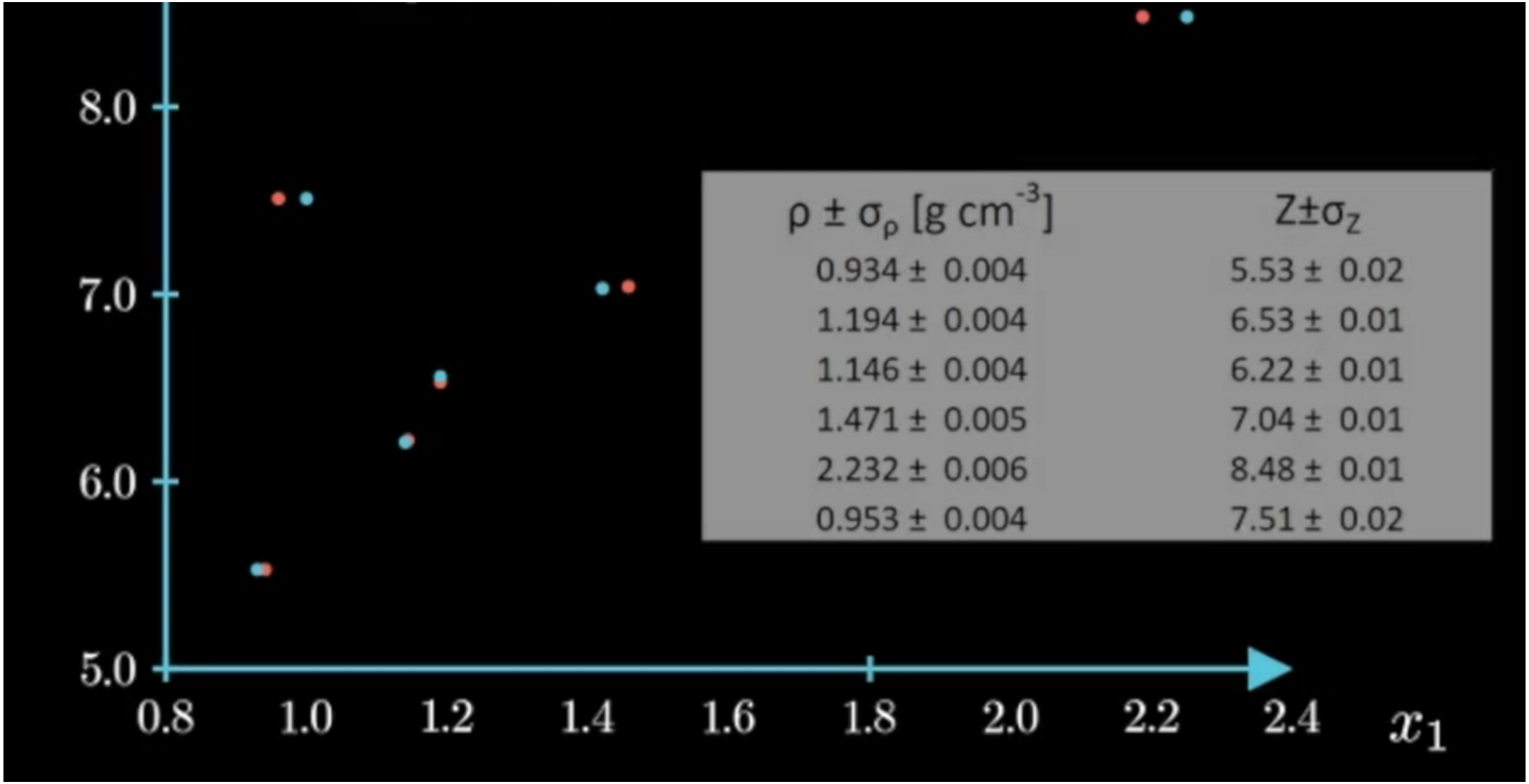

The 2D histogram with $x_1$ and $x_2$ on the horizontal and vertical axes
$x_2$
$x_1$
Blurred spots are fitted with 2D Gaussian functions

Applying the rotation and then dividing the second rotated coordinate by the first one



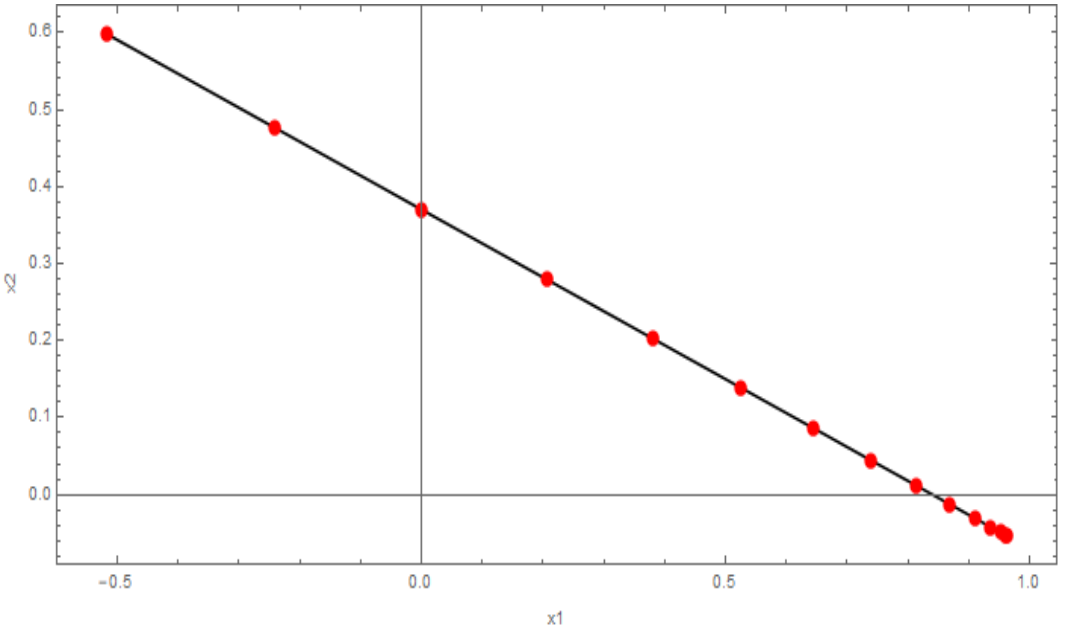

Effective atomic number $Z_{eff}$ calibration curve:
$x_Z = pZ^{n-1} + q$
−1.0
−2.0
−3.0
5.0
6.0
7.0
8.0
9.0
10.0
$Z_{eff}$

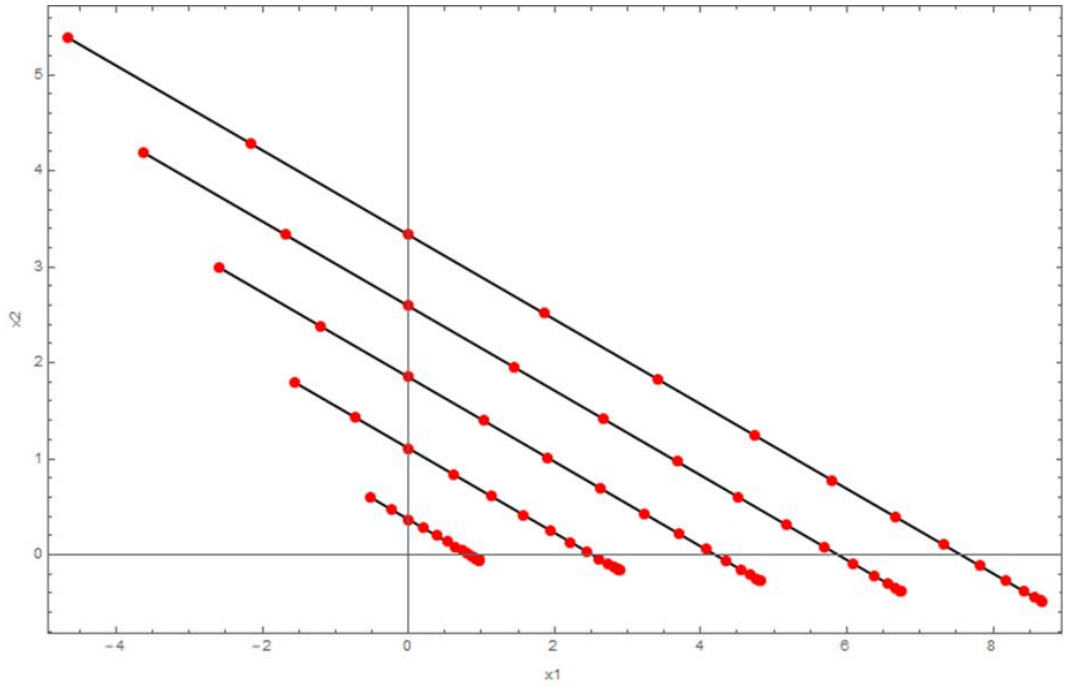

Material density calibration curve:
$x_\rho = r\rho + s$
$x_\rho$
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
Density [g $cm^{-3}$]

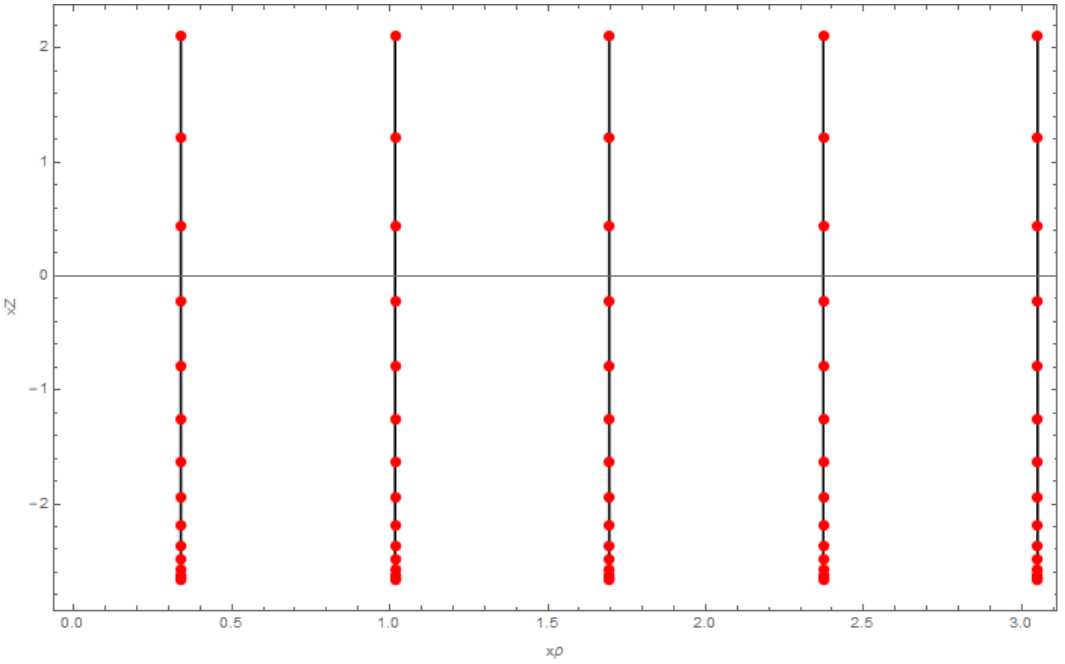


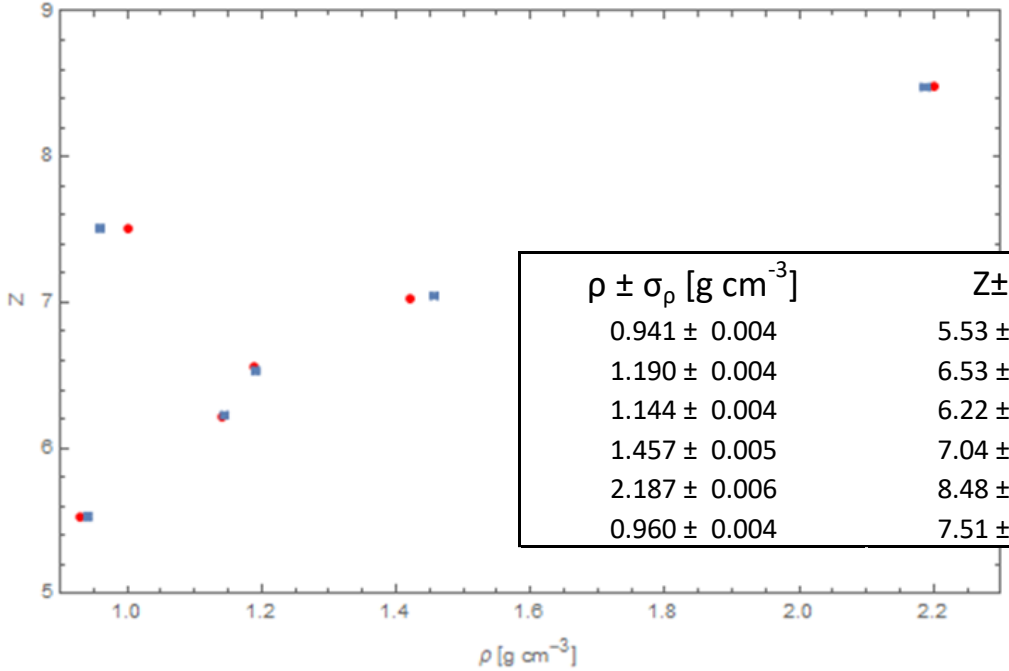

| $\rho \pm \sigma_\rho$ [g cm$^{-3}$] | $Z \pm \sigma_Z$ |
|---|---|
| 0.934 ± 0.004 | 5.53 ± 0.02 |
| 1.194 ± 0.004 | 6.53 ± 0.01 |
| 1.146 ± 0.004 | 6.22 ± 0.01 |
| 1.471 ± 0.005 | 7.04 ± 0.01 |
| 2.232 ± 0.006 | 8.48 ± 0.01 |
| 0.953 ± 0.004 | 7.51 ± 0.02 |

Original graphs:




| ρ ± $\sigma_\rho$ [g cm$^{-3}$] | Z±$\sigma_Z$ |
|---|---|
| 0.941 ± 0.004 | 5.53 ± 0.02 |
| 1.190 ± 0.004 | 6.53 ± 0.01 |
| 1.144 ± 0.004 | 6.22 ± 0.01 |
| 1.457 ± 0.005 | 7.04 ± 0.01 |
| 2.187 ± 0.006 | 8.48 ± 0.01 |
| 0.960 ± 0.004 | 7.51 ± 0.02 |