



SUNDHEDSSTYRELSEN

# **"Transmission"**

## **Validation of assumed material composition (and the fine art of seasoning)**



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# Unknown sample composition

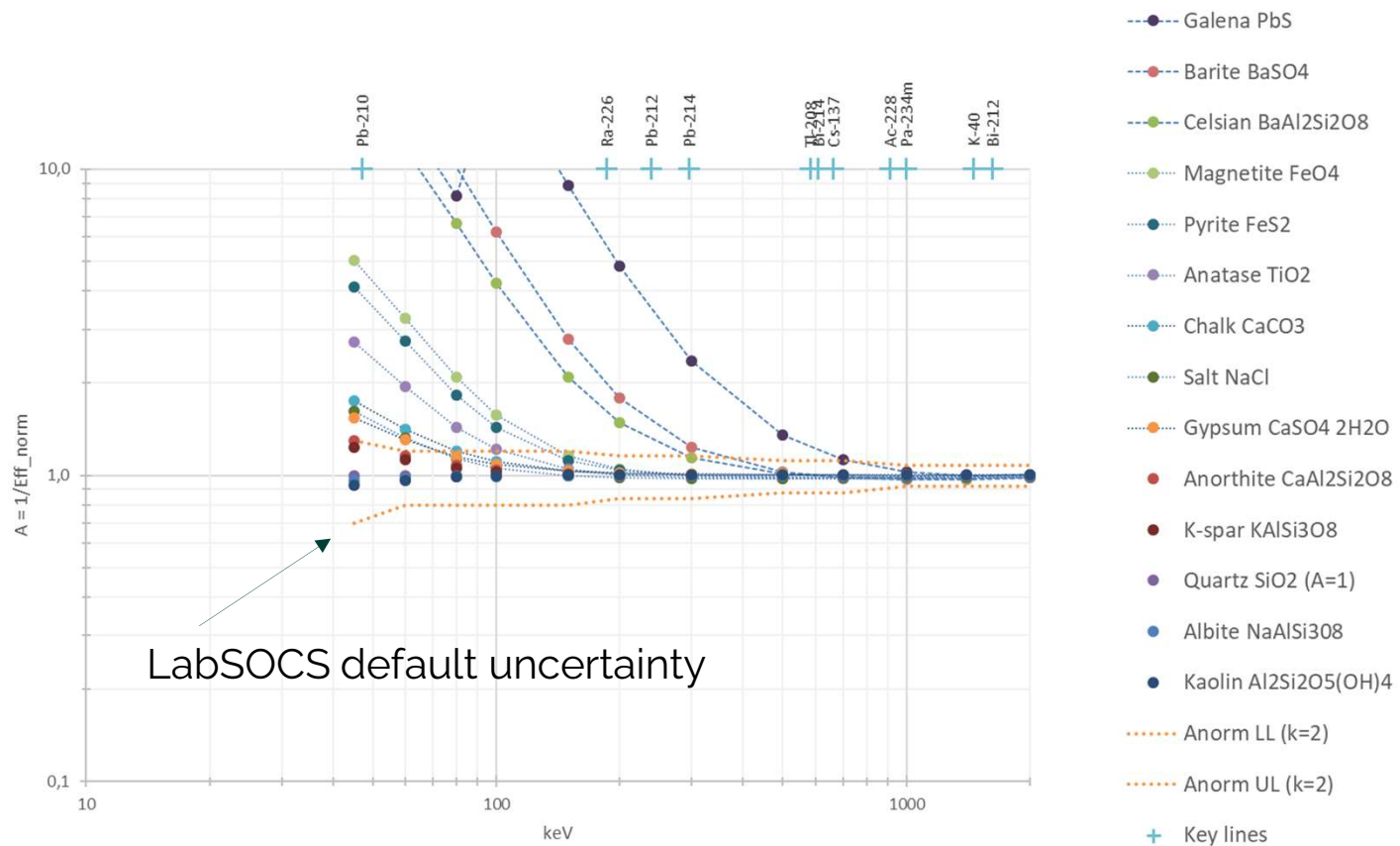
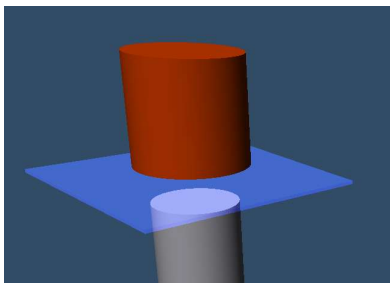
?



## Periodic Table of the Elements

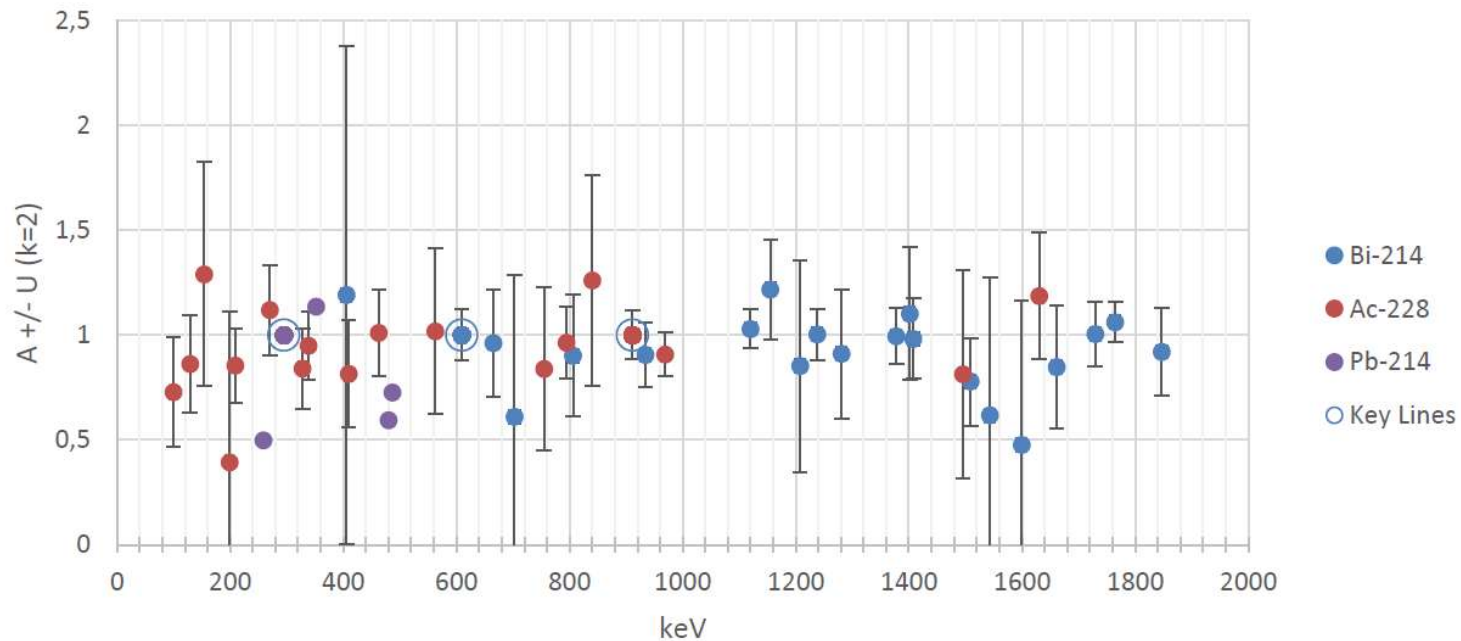
|                                   |                                   |                                  |                                 |                                       |                                 |                                    |                                   |                                   |                                  |                                    |                                     |                                     |                                 |                                      |                                   |                                     |                                     |                                      |
|-----------------------------------|-----------------------------------|----------------------------------|---------------------------------|---------------------------------------|---------------------------------|------------------------------------|-----------------------------------|-----------------------------------|----------------------------------|------------------------------------|-------------------------------------|-------------------------------------|---------------------------------|--------------------------------------|-----------------------------------|-------------------------------------|-------------------------------------|--------------------------------------|
| 1<br>IA<br>H<br>Hydrogen<br>1.008 | 2<br>IIA<br>He<br>Helium<br>4.003 |                                  |                                 |                                       |                                 |                                    |                                   |                                   |                                  |                                    |                                     |                                     |                                 |                                      |                                   |                                     |                                     | 18<br>VIIIA<br>Ar<br>Argon<br>39.948 |
| 3<br>Li<br>Lithium<br>6.941       | 4<br>Be<br>Beryllium<br>9.012     |                                  |                                 |                                       |                                 |                                    |                                   |                                   |                                  |                                    |                                     |                                     |                                 |                                      |                                   |                                     |                                     | 19<br>K<br>Potassium<br>39.098       |
| 5<br>Na<br>Sodium<br>22.990       | 6<br>Mg<br>Magnesium<br>24.305    |                                  |                                 |                                       |                                 |                                    |                                   |                                   |                                  |                                    |                                     |                                     |                                 |                                      |                                   |                                     |                                     | 20<br>Ca<br>Calcium<br>40.078        |
| 7<br>Sc<br>Scandium<br>44.956     | 8<br>Ti<br>Titanium<br>47.88      | 9<br>V<br>Vanadium<br>50.942     | 10<br>Cr<br>Chromium<br>51.996  | 11<br>Mn<br>Manganese<br>54.938       | 12<br>Fe<br>Iron<br>55.845      | 13<br>Co<br>Cobalt<br>58.933       | 14<br>Ni<br>Nickel<br>58.693      | 15<br>Cu<br>Copper<br>63.546      | 16<br>Zn<br>Zinc<br>65.38        | 17<br>Ga<br>Gallium<br>69.723      | 18<br>Ge<br>Germanium<br>72.63      | 19<br>As<br>Arsenic<br>74.922       | 20<br>Se<br>Selenium<br>78.96   | 21<br>Br<br>Bromine<br>79.904        | 22<br>Kr<br>Krypton<br>83.80      |                                     |                                     | 36<br>Kr<br>Krypton<br>83.80         |
| 23<br>Rb<br>Rubidium<br>85.468    | 24<br>Sr<br>Strontium<br>87.62    | 25<br>Y<br>Yttrium<br>88.906     | 26<br>Zr<br>Zirconium<br>91.224 | 27<br>Nb<br>Niobium<br>92.906         | 28<br>Mo<br>Molybdenum<br>95.94 | 29<br>Tc<br>Technetium<br>98.906   | 30<br>Ru<br>Ruthenium<br>101.07   | 31<br>Rh<br>Rhodium<br>102.91     | 32<br>Pd<br>Palladium<br>106.36  | 33<br>Ag<br>Silver<br>107.868      | 34<br>Cd<br>Cadmium<br>112.411      | 35<br>In<br>Indium<br>114.818       | 36<br>Sn<br>Tin<br>118.710      | 37<br>Sb<br>Antimony<br>121.757      | 38<br>Te<br>Tellurium<br>127.6    | 39<br>I<br>Iodine<br>126.905        | 40<br>Xe<br>Xenon<br>131.29         | 54<br>Xe<br>Xenon<br>131.29          |
| 39<br>Cs<br>Cesium<br>132.905     | 40<br>Ba<br>Barium<br>137.327     | 41<br>La<br>Lanthanum<br>138.905 | 42<br>Ce<br>Cerium<br>140.12    | 43<br>Pr<br>Praseodymium<br>140.908   | 44<br>Nd<br>Neodymium<br>144.24 | 45<br>Pm<br>Promethium<br>144.913  | 46<br>Sm<br>Samarium<br>150.36    | 47<br>Eu<br>Europium<br>151.964   | 48<br>Gd<br>Gadolinium<br>157.25 | 49<br>Tb<br>Terbium<br>158.925     | 50<br>Dy<br>Dysprosium<br>162.50    | 51<br>Ho<br>Holmium<br>164.930      | 52<br>Er<br>Erbium<br>167.259   | 53<br>Tm<br>Thulium<br>168.930       | 54<br>Yb<br>Ytterbium<br>173.054  | 55<br>Lu<br>Lutetium<br>174.967     | 56<br>Hf<br>Hafnium<br>178.49       | 72<br>Hf<br>Hafnium<br>178.49        |
| 57<br>Fr<br>Francium<br>223.018   | 58<br>Ra<br>Radium<br>226.025     | 59-71<br>Actinides               | 72<br>Th<br>Thorium<br>232.0377 | 73<br>Pa<br>Protactinium<br>231.03688 | 74<br>U<br>Uranium<br>238.02891 | 75<br>Np<br>Neptunium<br>237.04817 | 76<br>Pu<br>Plutonium<br>244.0642 | 77<br>Am<br>Americium<br>243.0613 | 78<br>Cm<br>Curium<br>247.0753   | 79<br>Bk<br>Berkelium<br>247.07125 | 80<br>Cf<br>Californium<br>251.0833 | 81<br>Es<br>Einsteinium<br>252.0833 | 82<br>Fm<br>Fermium<br>257.1015 | 83<br>Md<br>Mendelevium<br>258.10528 | 84<br>No<br>Nobelium<br>259.10858 | 85<br>Lr<br>Lawrencium<br>262.10937 | 86<br>Ts<br>Tennessine<br>289.10156 | 118<br>Og<br>Oganesson<br>289.10156  |
|                                   |                                   |                                  |                                 |                                       |                                 |                                    |                                   |                                   |                                  |                                    |                                     |                                     |                                 |                                      |                                   |                                     |                                     | 86<br>Rn<br>Radon<br>222.01758       |
|                                   |                                   |                                  |                                 |                                       |                                 |                                    |                                   |                                   |                                  |                                    |                                     |                                     |                                 |                                      |                                   |                                     |                                     | 86<br>Rn<br>Radon<br>222.01758       |

# Heavy elements (e.g. Ba) are critical for lower energies – at same density



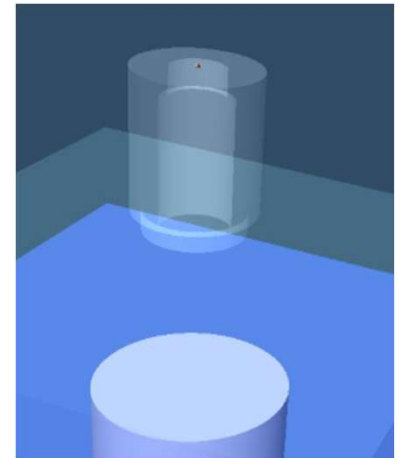
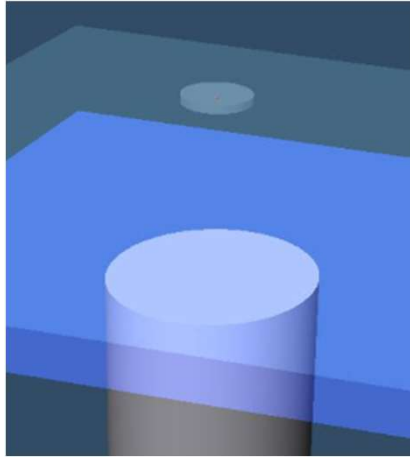
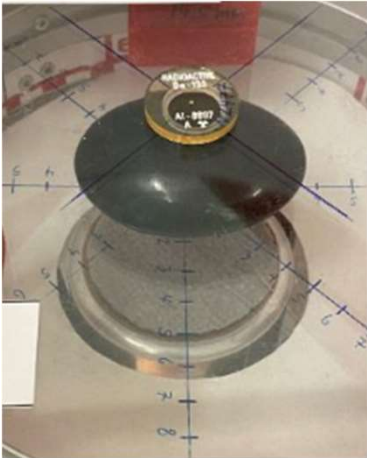
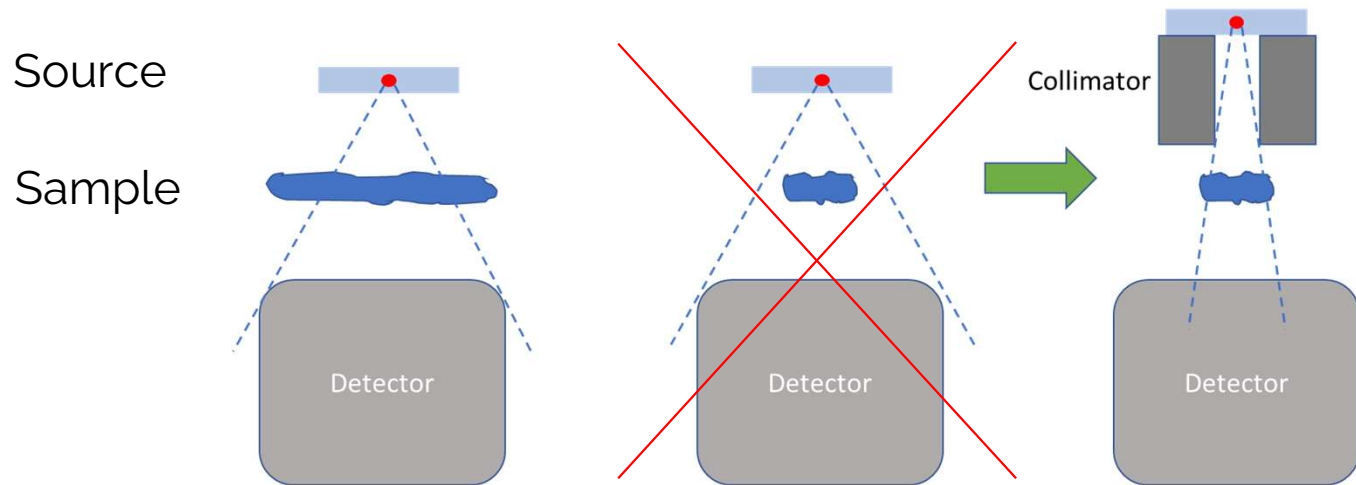
# LACE: Line Activity Consistency Evaluation

Should be horizontal, QC: No significant correlation ( $p > 0,05$ )



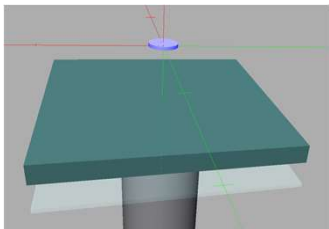
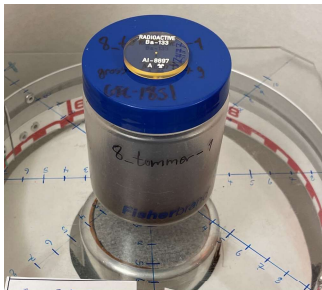
$r$ : Pearson corr. coeff.     $t_{\text{corr}} = r \cdot \sqrt{(n-2) / (1-r^2)}$      $p = T.DIST.2T(t_{\text{corr}}; (n-2))$

# "Transmission": Source on sample



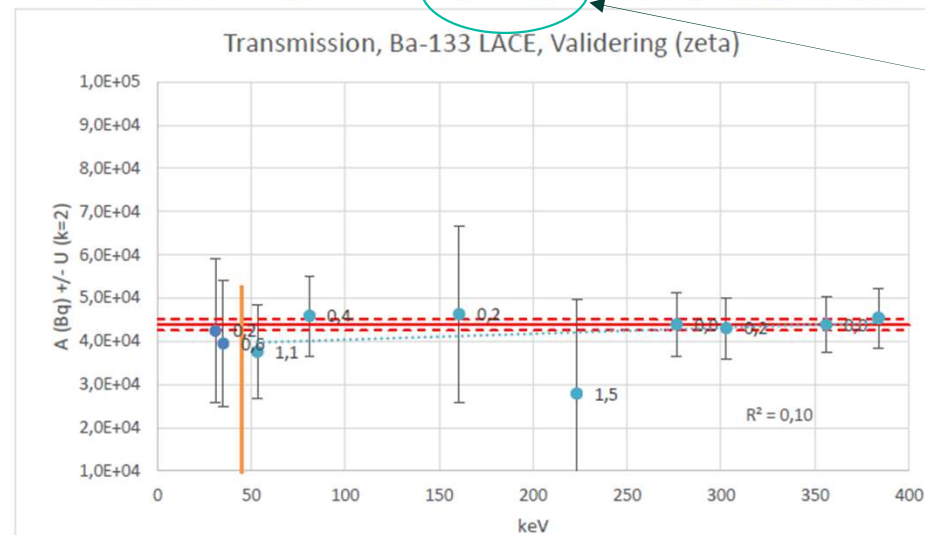
# "Transmission": Ba-133 LACE and validation

For energies above lowest reported (45 keV)



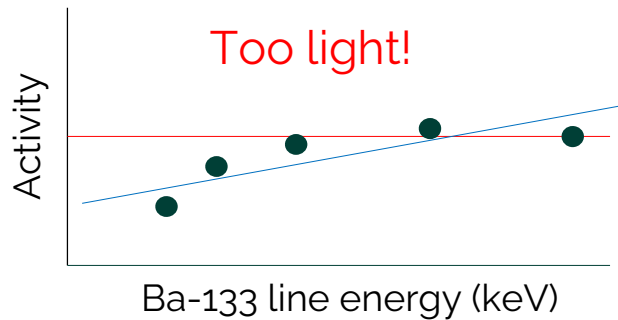
| Påviste (keV) | A (Bq)   | u(A)    | CSC  | Diff (%) | zeta | zeta < 2 ? |
|---------------|----------|---------|------|----------|------|------------|
| 30,8          | 4,24E+04 | 8,4E+03 | 1,00 | -3%      | 0,2  | -          |
| 35,1          | 3,95E+04 | 7,3E+03 | 1,00 | -10%     | 0,6  | -          |
| -             | -        | -       | -    | -        | -    | -          |
| 53,2          | 3,76E+04 | 5,4E+03 | 0,98 | -14%     | 1,1  | SAND       |
| 80,9          | 4,59E+04 | 4,6E+03 | 0,98 | 5%       | 0,4  | SAND       |
| 160,6         | 4,63E+04 | 1,0E+04 | miss | 6%       | 0,2  | SAND       |
| 223,2         | 2,79E+04 | 1,1E+04 | miss | -36%     | 1,5  | SAND       |
| 276,4         | 4,39E+04 | 3,7E+03 | 0,98 | 0%       | 0,0  | SAND       |
| 302,9         | 4,30E+04 | 3,5E+03 | 0,98 | -2%      | 0,2  | SAND       |
| 356,0         | 4,38E+04 | 3,3E+03 | 0,99 | 0%       | 0,0  | SAND       |
| 383,9         | 4,54E+04 | 3,5E+03 | 1,00 | 4%       | 0,5  | SAND       |
| -             | -        | -       | -    | -        | -    | -          |

Pearson r<sup>2</sup>: 0,10      p: **0,37**      OK hvis p > 0,05 (DokID 3867)

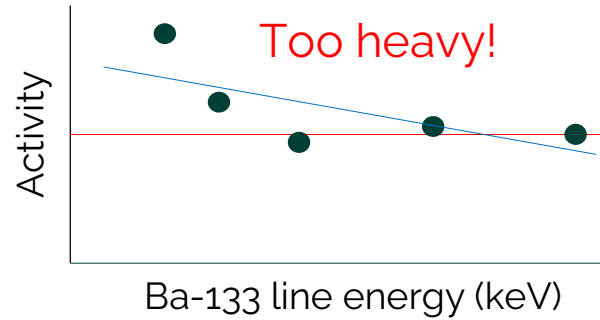


QC  
zeta < 2  
p(Pearson) > 0,05

# QC iteration - Composition fine-tuning



Add heavy element(s)



Remove heavy element(s)



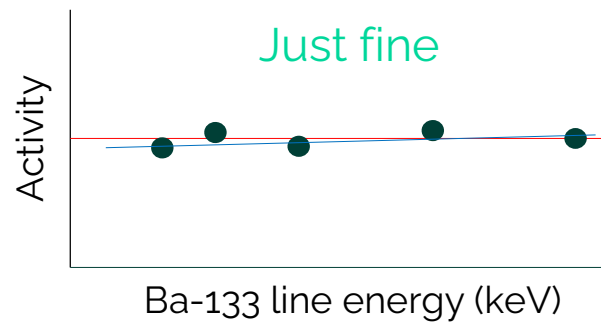
>> CONSTANT DENSITY <<



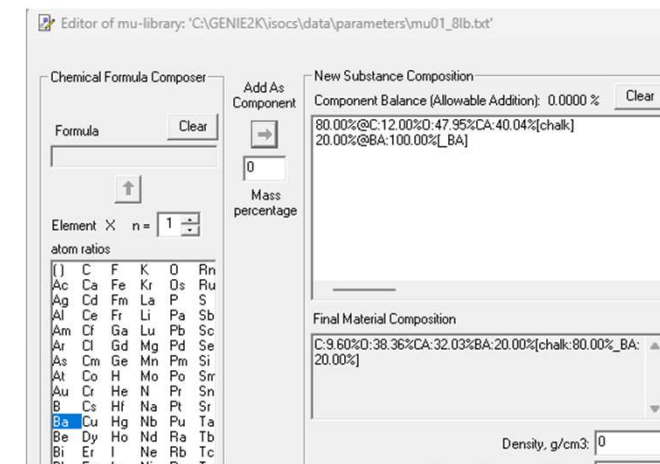
...



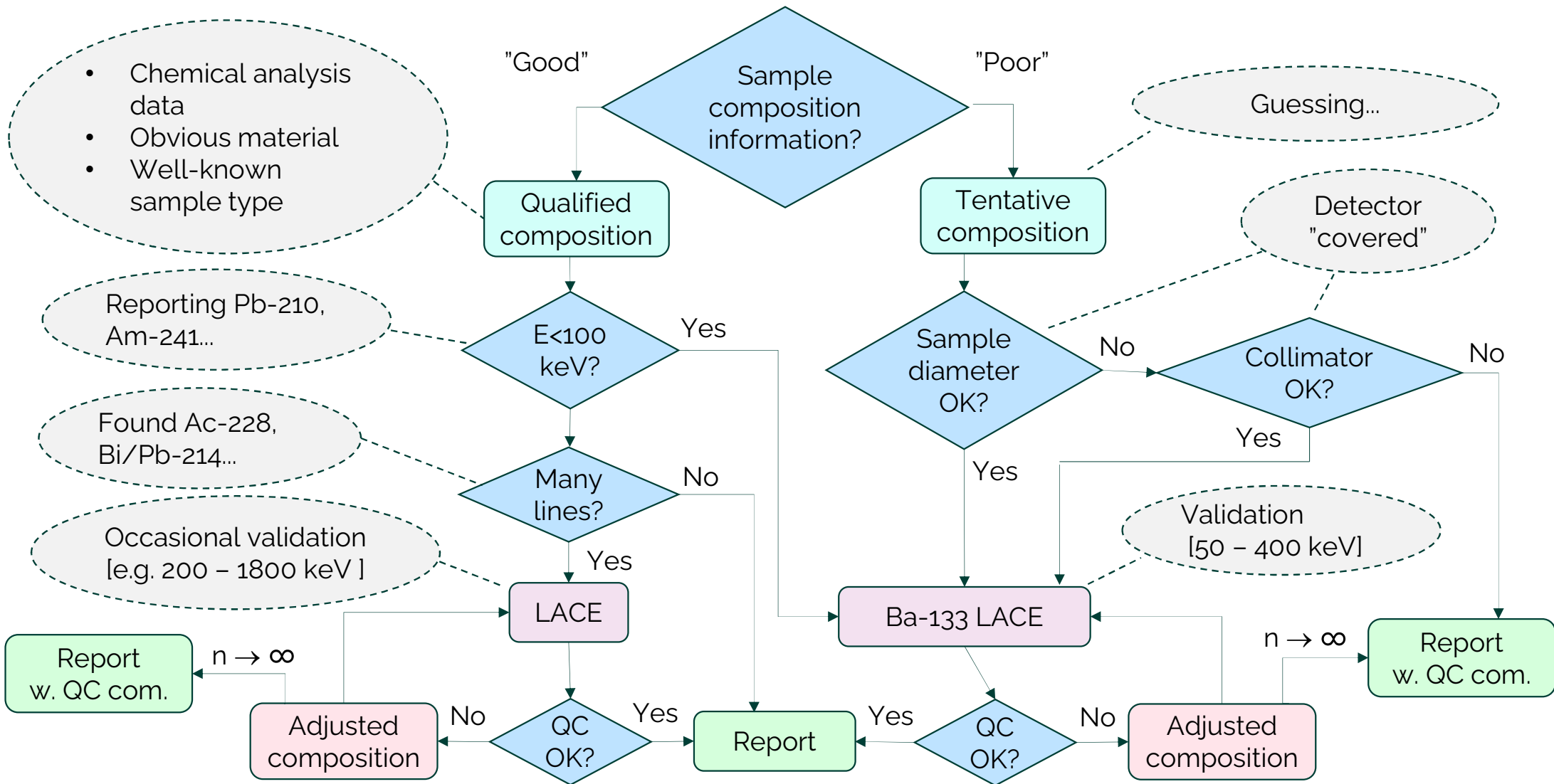
Typically  $n < 5$



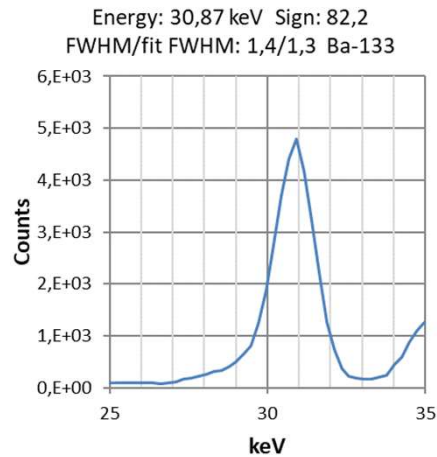
QC:  
 $p(\text{Pearson}) > 0,05$   
 $\text{zeta} < 2$



# Workflow



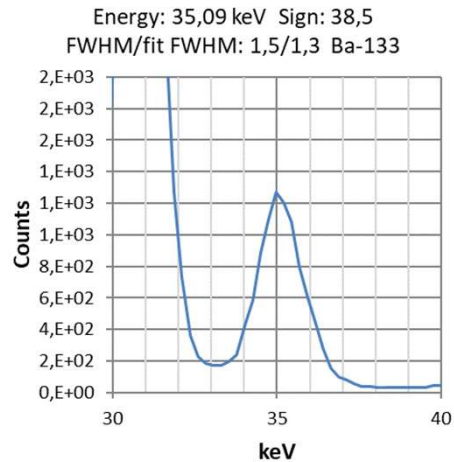
# Merging of unresolved Ba-133 lines



30.62 keV (33.8%)  
30.97 keV (62.4%)



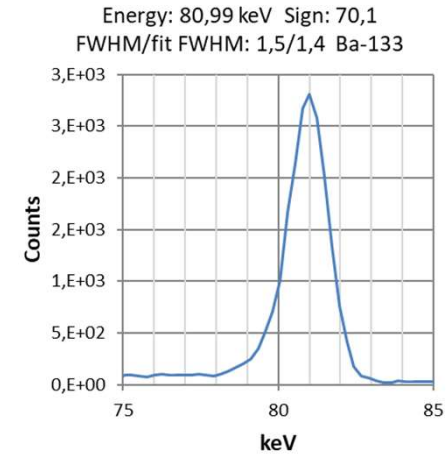
30.8 keV (96.2%)



35.05 keV (18.24%)  
35.90 keV (4.45%)



35.2 keV (22.7%)



79.61 keV (2.63%)  
81.00 keV (33.31%)



80.9 keV (35.9%)

Peaks are somewhat broader than expected (FWHM vs fit)