Rad Detection limits

Simplified?

Always a signal

Radiation detection devices in the laboratory are very sensitive and almost always register some sort of signal – even when there is no activity present.

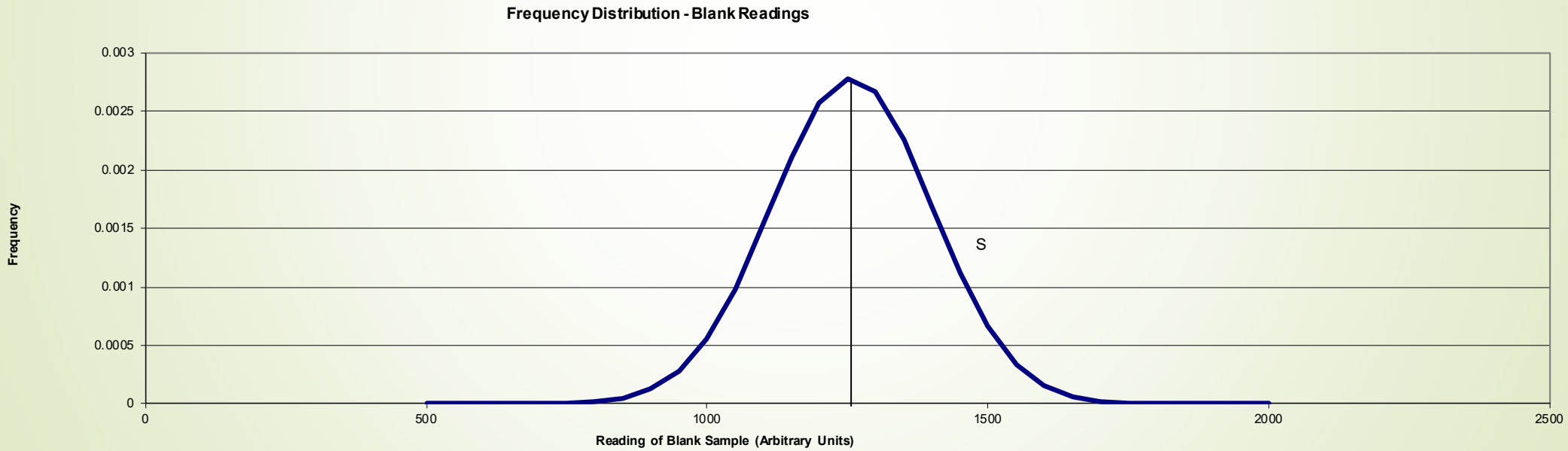
Gamma detectors	Liquid Scintillation counters	Gas flow proportional counters

Like when you have frisker with a pancake probe over in the corner Click . . . Click…Click...Click…Click…

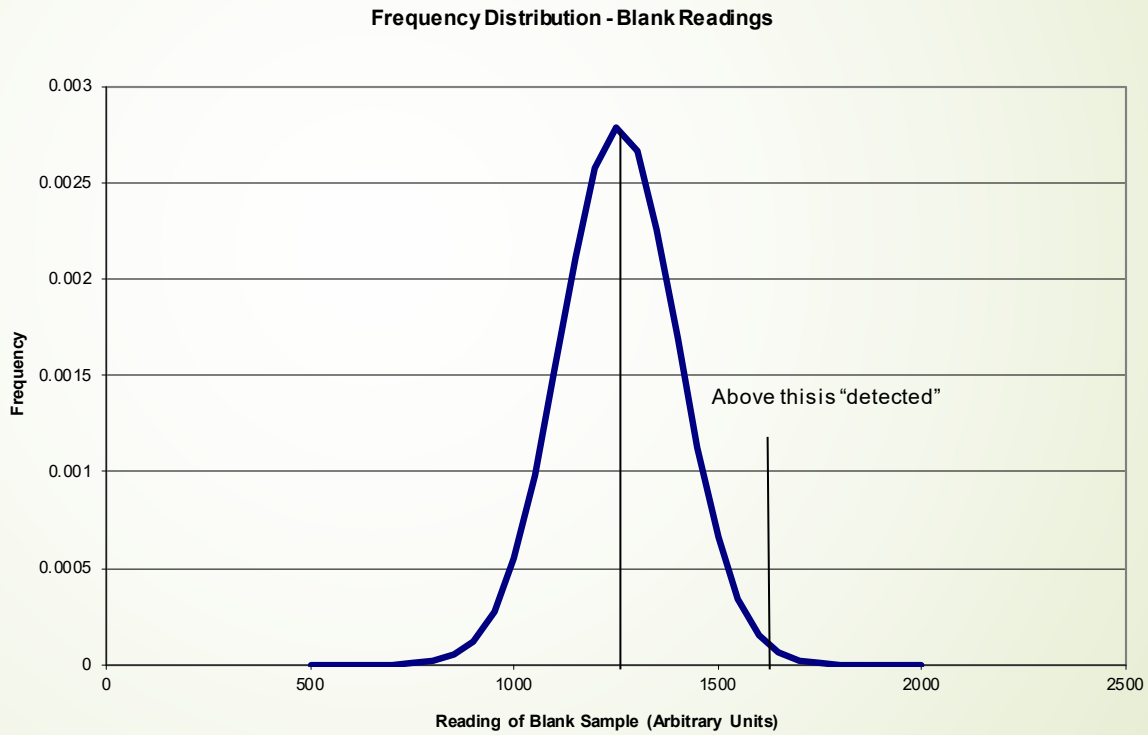
Always a signal

- We call this the “background” or “blank” signal
  - It comes from naturally occurring radioactivity in surrounding building materials like concrete and brick, in the air, and may come from machine “noise”. There is still the presence of fallout from atmospheric weapons tests.
    - But Alpha Spectrometers can be very, very clean and have only very few “counts” or even zero…… See MARLAP chapter 20

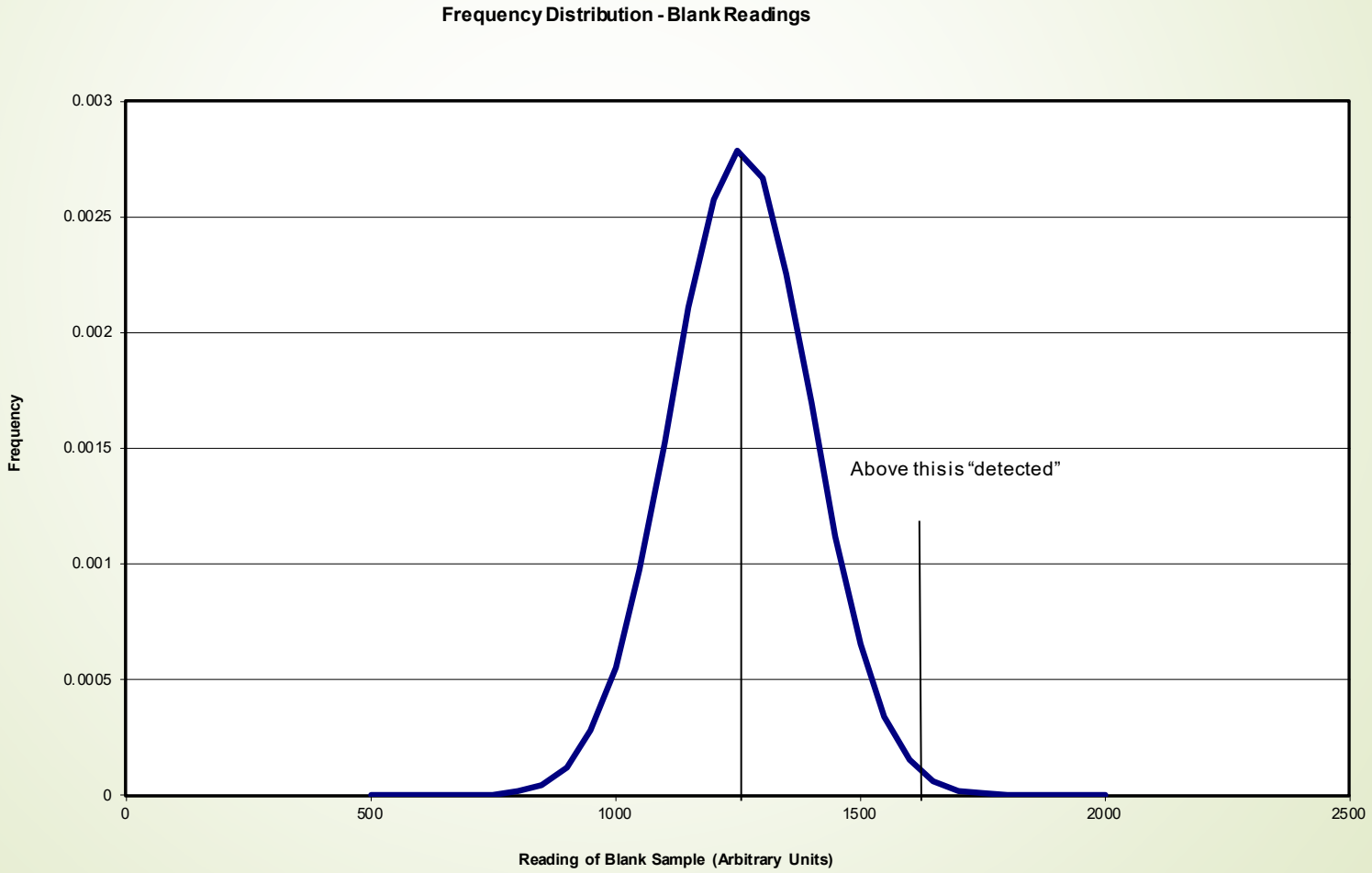
And as you might imagine we can characterize the blank signal by a mean and standard deviation. Individual readings are sometimes higher and sometimes lower than the average

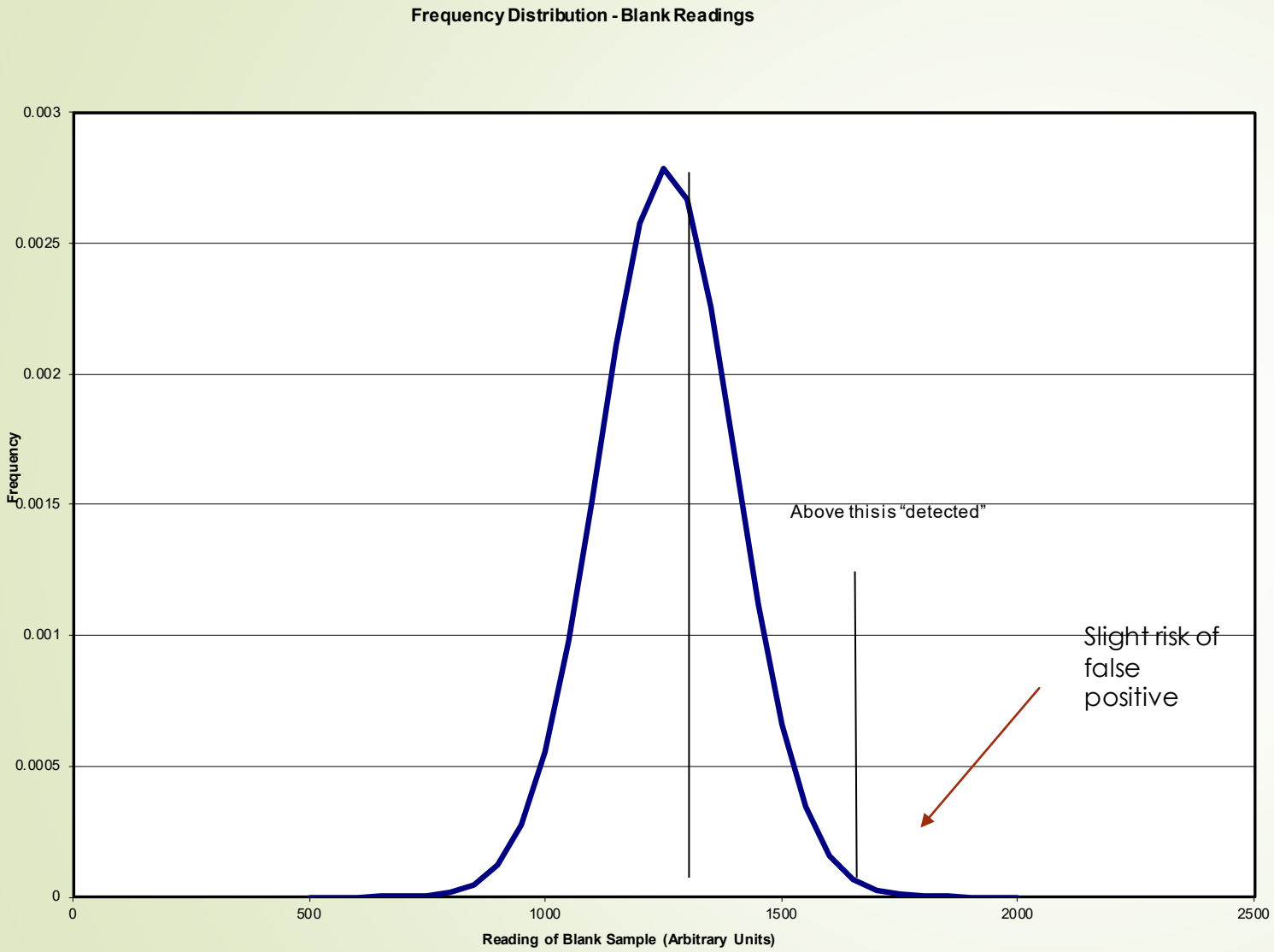


So how different from background does a signal have to be to be classified as “detected”?



But no matter what point we select as our decision point, there is a possibility that a true blank sample might measure above it, since the distribution is open-ended to the right.





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Risk Has to be Defined

The project has to accept a risk of a false positive.

It can't be zero

It is usually 5% but some projects use 1%.

Statistics are well defined

- **Lc_5 = 2.33 * St_DevBk at 5% risk**
- **Lc_1 = 3.29 * St_DevBk at 1% risk**
- **Where Lc is called the "critical level" or "decision level"**
  - **Simplistically, the standard deviation of the background is the Square Root of the net Background counts.**
  - **The 2.33 and 3.29 are values in standard statistical tables times SQRT(2)**
  - **The equations presented are in simplest form - as counts**

A project defines / accepts a risk of

A false positive

- The probability of saying something is there when it is not
- Or as statisticians say - "Type I Risk"

And in doing that, the project defines how to calculate detection limit / critical level / decision level

Detection Decision

So a lab happily runs samples and calculate the Critical Level for that day and reports

"Our critical level is 10 pCi. All your samples were not detected, by the way. "

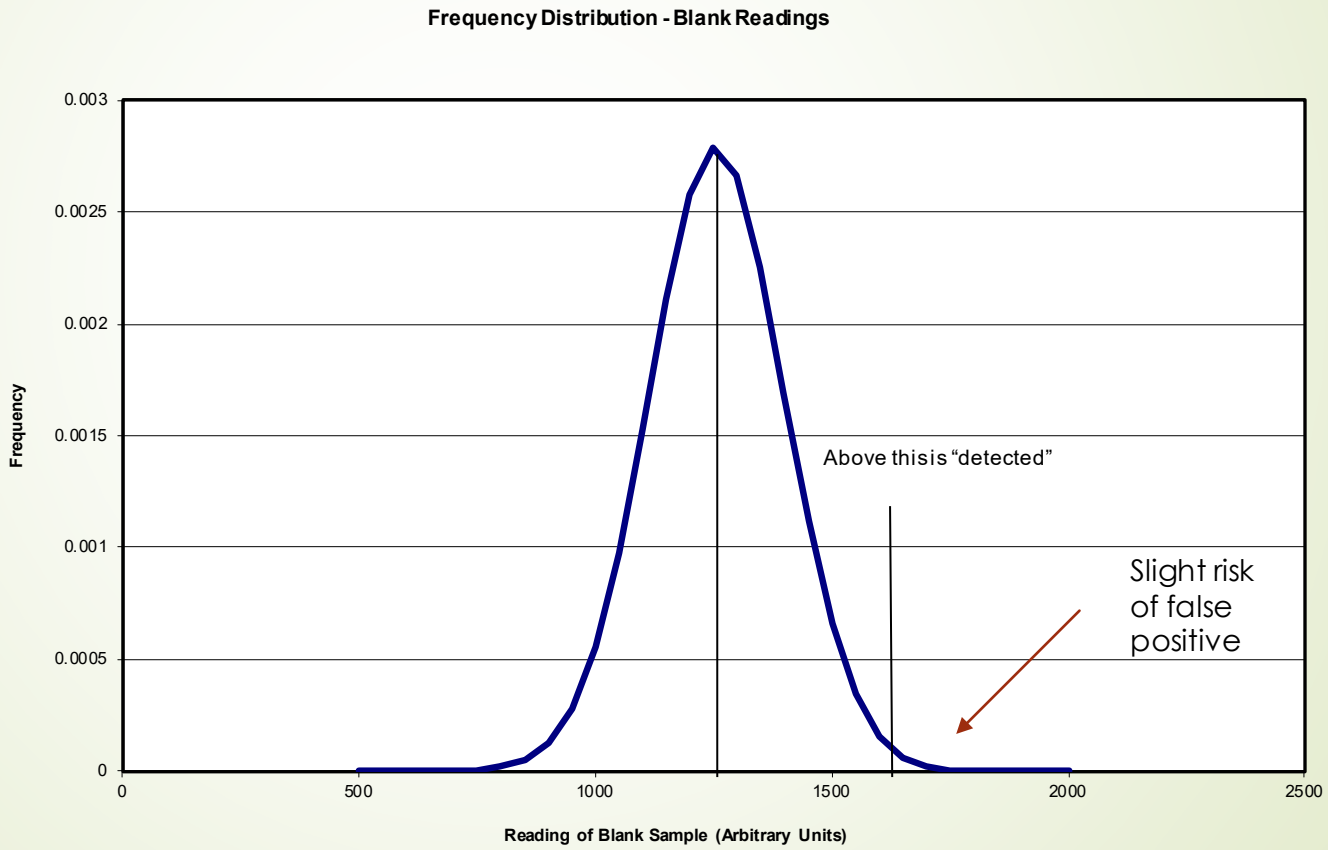
The client responds "So you are telling me that if I give you a thousand samples, all of them with 10 pCi you can guarantee that you would have detected all of them?

And then management, regulators, and lawyers got involved – a hypothetical conversation from 1960

And the lab responds -

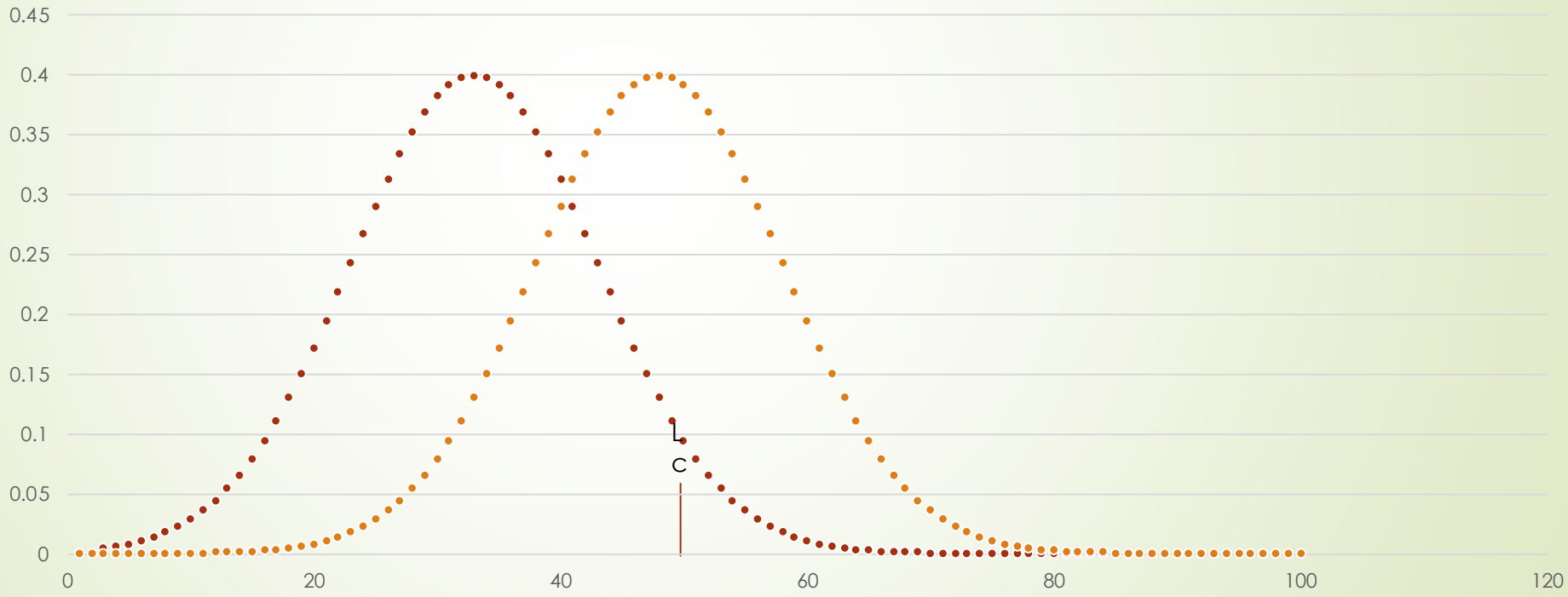
- **Well, no. We would have had a 50-50 chance of seeing any one of the samples as "detected" if the true activity was right at our critical level.**
- **WHAT!!!!????? 50-50!! I can't accept risk like that!!!!**
- **So how much activity has to be there to see it more than 50% of the time? (intense breathing . . .)**
  - **But before we go on we want to make sure everyone understands why we say 50-50**

If activity in a sample happened to be right at the Lc, it would be distributed in a curve very similar to the blank curve. Half of it would fall above and half would fall below the Lc.

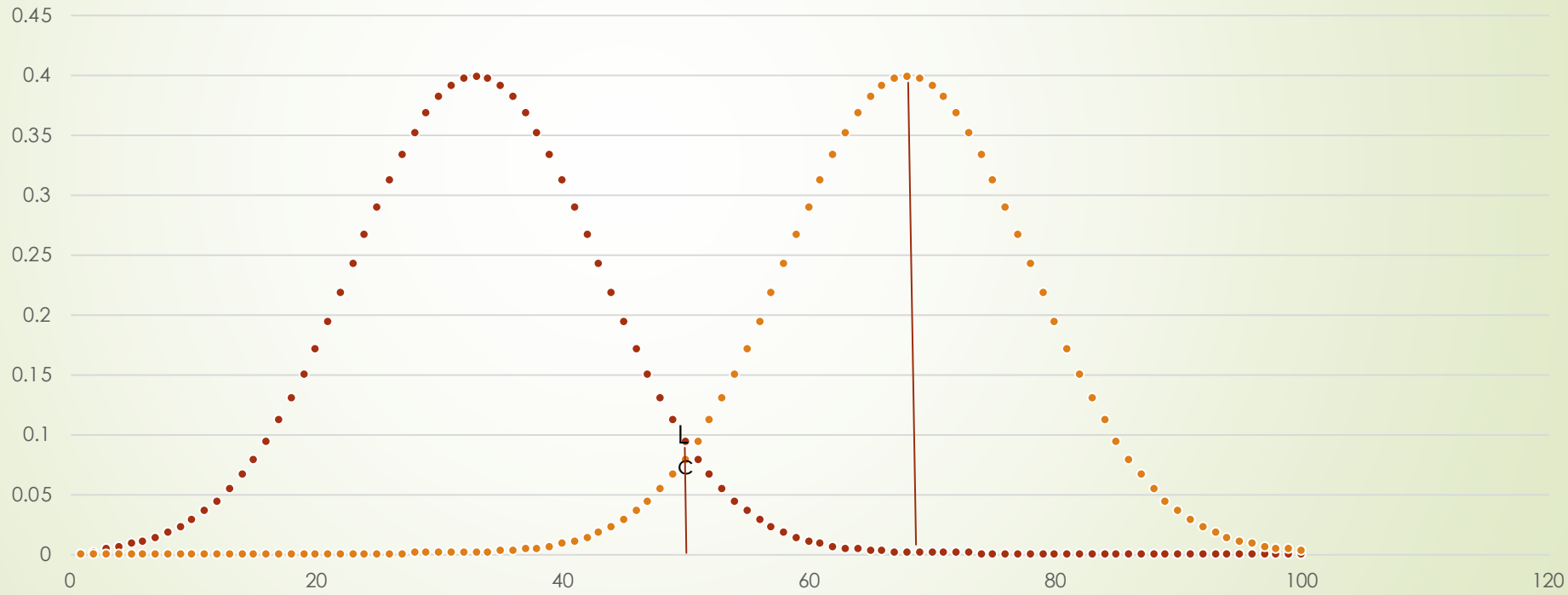


See illustrative drawings presented next.

Blank signal – maroon points
Sample at Lc – orange points
About half the time, the sample signal falls below the Lc



“Most of the time”, the sample distribution falls above the Lc



What do you mean by . . . . ?

So the lab continues – "Help us out here. What do you mean by how much activity has to be there to detect it most of the time?

And in answering that question, the project has to accept a risk of a false negative.

- The answer cannot be 100% of the time or 0% risk of a false negative

Most of the rad literature and available equations are written assuming a 5% risk of a false negative.

Method Detection Limit / Minimum Detectable Concentration / Minimum Detectable Activity / Lower Limit of Detection

- MDA is NOT the point at which the detection decision is made. It is wrong to use it that way
  - NRC had people tabulate and report routinely achieved MDAs so maybe that is where the notion came from - - but it has been wrongly used for years
- Lc is the point at which the detection decision is made – either Lc_1 or Lc_5 or another risk accepted by the project

Method Detection Limit / Minimum Detectable Concentration / Minimum Detectable Activity

- So the MDA is the amount of activity that must be present to detect 95% of the time (assuming a 5% risk of a false positive on the detection decision).
- It is a "before I measure" value
  - Tells me what I am "likely to see" in that it will fall above the Lc
    - And by "likely" we mean 95% of the time
      - Or a 5% risk of a false negative (Type II error)

Method Detection Limit / Minimum Detectable Concentration / Minimum Detectable Activity

- **Most labs can handle Lc_1, Lc_5, or MDA as the detection decision point.**
  - **That is, the point below which they apply the "U" qualifier.**
    - **All our labs report Result, Counting Uncertainty, Total Uncertainty, and MDA**
      - **Some report both Lc and MDA.**
  - **But all labs calculate the "standard" MDA based on a 5% risk of a false positive and a 5% risk of a false negative.**

Equations ranked in order of size (decreasing)

- MDA = 2.7 + 4.66 * SQRT(Bk)
- Lc_1 = 3.29 * SQRT (Bk)
- Lc_5 = 2.33 * SQRT (Bk)

  - Each of these is in "counts" and would be multiplied by a factor containing counting efficiency, count time, chemical yield, units factors, and so forth for your final reported value

- What does it mean that it is wrong to use the MDA as the point at which I make my detection decision?
  - Well, we do it all the time and have done it for decades
  - It carries <0.005% risk of a false positive
  - But for waste disposal decisions it is parallel to the PQL used in stable chemistry and can be used similarly

?

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- What is the down-side of going to 5% risk of a false positive for all our detection decisions and reports?
  - It means that if we sample 20 things and make 20 analyses on each: 400 measurements-
    - → we will have ~20 apparent detects we might have to explain to folks who do not understand technical things
  - Model this with a spreadsheet / random number generator to get a feel for it.
  - Or check out the summary page of a gamma isotopic report for a method blank where every isotope in the library is listed. See how many fall above the Lc_5

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Is there any way I can go back and re-evaluate historic data that were reported against the MDA?

Yes (qualified) – If you have access to the laboratory report, not just electronic data – you can see whether the lab actually tabulated the Lc_1 or Lc_5 along with the other data. Sometimes it is there.

If not, since the labs report Result, Counting Uncertainty, Total Uncertainty and MDA, you can

- **Estimate the Lc_5 as approximately 0.45 * MDA (Dr. Bill's rule of thumb)**
- **Estimate the Lc_5 as 2.33 * CU/1.965 . Similarly for Lc_1.**
  - **That may not work well if alpha spectrometry data detection utilized a "blank population" model – see MARLAP chapter 20**

What is the MDA good for, then?

When setting up a work request with a laboratory, it is important to provide a "requested MDA" that allows the lab to plan sample aliquots and count times to meet project needs

- It is the value the lab would be able to detect with confidence

The requested MDA should be smaller than any action level

- Example: A waste acceptance criterion is 10 pCi/g for Cs-137
  - Write specifications with the lab at 5 pCi/g as the MDA
  - Then the laboratory selects the sample volume and count time to meet your needs
- The laboratory will tell you whether they can meet your request or not

What is the MDA good for, then?

- **Warning – certain theoretically calculated risk levels are not presently achievable as MDAs at any laboratory in the country**

What is the MDA good for, then?

- In some regulatory arenas, a median MDA is reported annually for each isotope of concern and sampling medium ---- proof that program design is adequately sensitive

What Else?

- When requested to lower a previously-established detection limit, the laboratory can increase count time, but the time is increased by the square of the ratio of the two MDAs
  - Simplistic example – for the past twenty years the project requested 10 pCi/g of Cs-137 – but today they ask for 0.1 pCi/g
  - The ratio of the two MDAs is 10/0.1 = 100
  - The count time would have to be increased by a factor of 100 x 100 =10,000
  - The other option is to increase the sample volume by a factor of 100
    - Decreases in MDA by factors of 2 to 5 could be in the realm of possibility because of changes in technology (more efficient detectors) or other considerations

What else?

- In times past there appears to have been confusion whether the MDA was sample-specific or some sort of “median” MDAs for a particular analytical technique. An explicit statement was required per the QSM
  - In my experience for the past 30 years, the MDA reported with Result, Counting Uncertainty, and Total Uncertainty has always been sample-specific

And Lastly

Just like the PQL in standard chemistry can be used as the point whether or not to have a "U" on the reported data for administrative reasons

The sample-specific MDA is often useful as the point at which a U-qualifier is applied in the reported data

Helpful Equations

$$MDA = 2.7 + 4.66 * SQRT(Bk)$$

$$Lc\_1 = 3.29 * SQRT\ (Bk)$$

$$Lc\_5 = 2.33 * SQRT\ (Bk)$$

- Estimate $Lc\_5 = \sim 0.45 * MDA$
- Estimate $Lc\_1 = \sim 0.64 * MDA$