The Science of Quality Assurance Indicators & Technique Analysis

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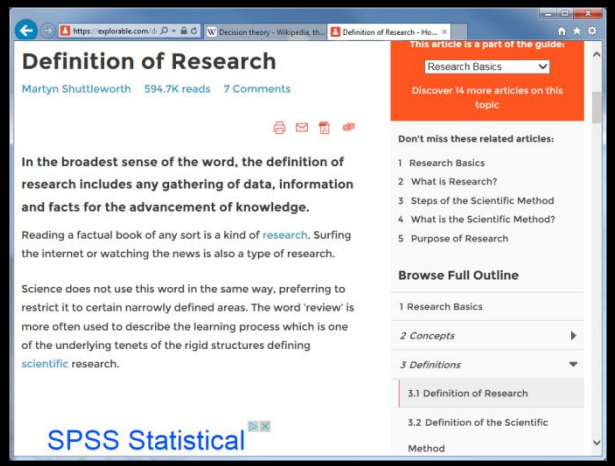
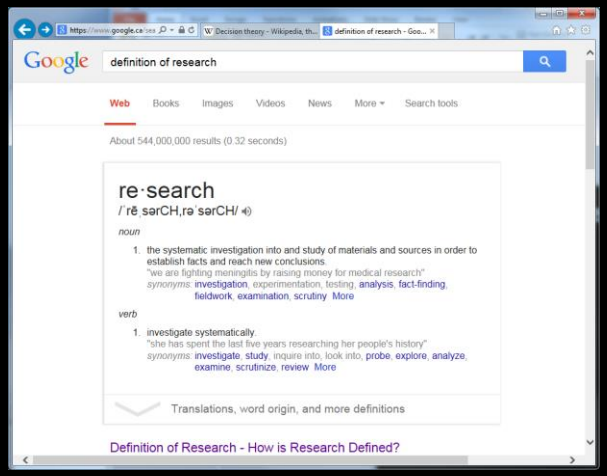
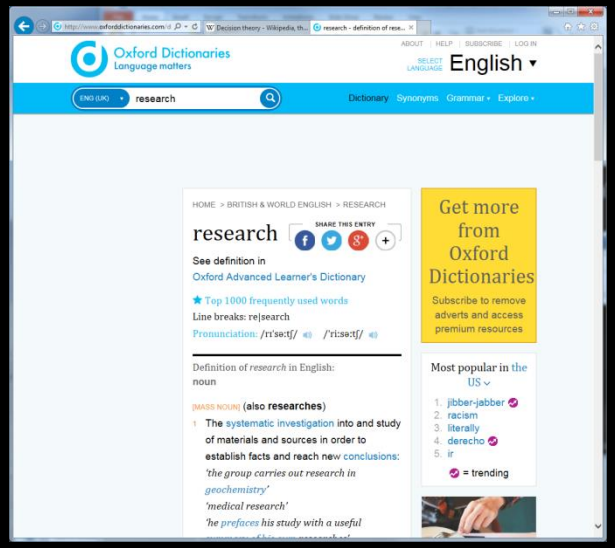
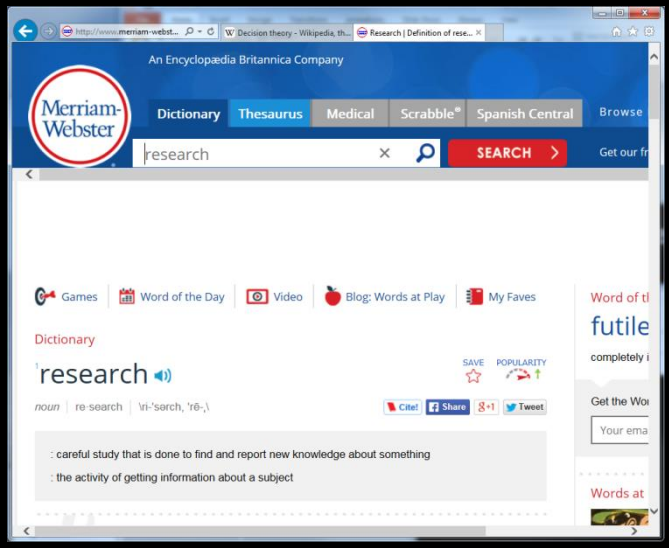
What is research?









Quality Improvement vs. Research

Quality Improvement vs. Research

Quality Improvements

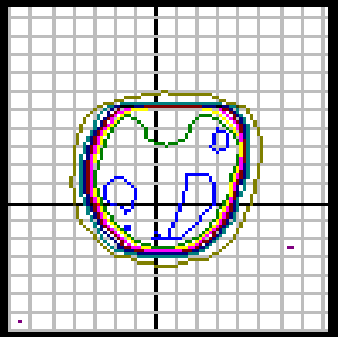
- Intent is to ***improve current practice***. For internal use only.
- Action is ***within existing standards of care***.
  - The knowledge is the same, but we can apply it in a better manner.

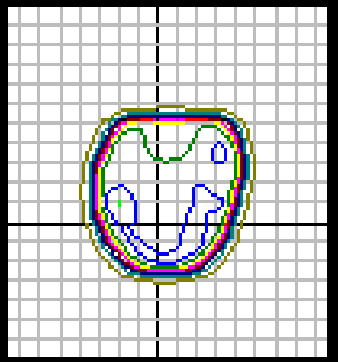
Research

- Intended to create ***generalized knowledge***.
- Desire to publish or present.
  - Data must be relevant *outside the institution*.
- Testing new methods.
  - *Perhaps new standards of care?*

What is Patient Specific QA?

- **Fundamentally, this is a beam diagnosis test.**
- **The purpose is to identify radiation beams that are “different” than the planned radiation beam.**
- **Most methods used to evaluate the result are physics & clinically based:**
  - **Dose & distance to agreement**
  - **Plan objectives, DVH, etc**
- **Are the usual metrics *generalizable*?**





Dosimetry vs. Imaging

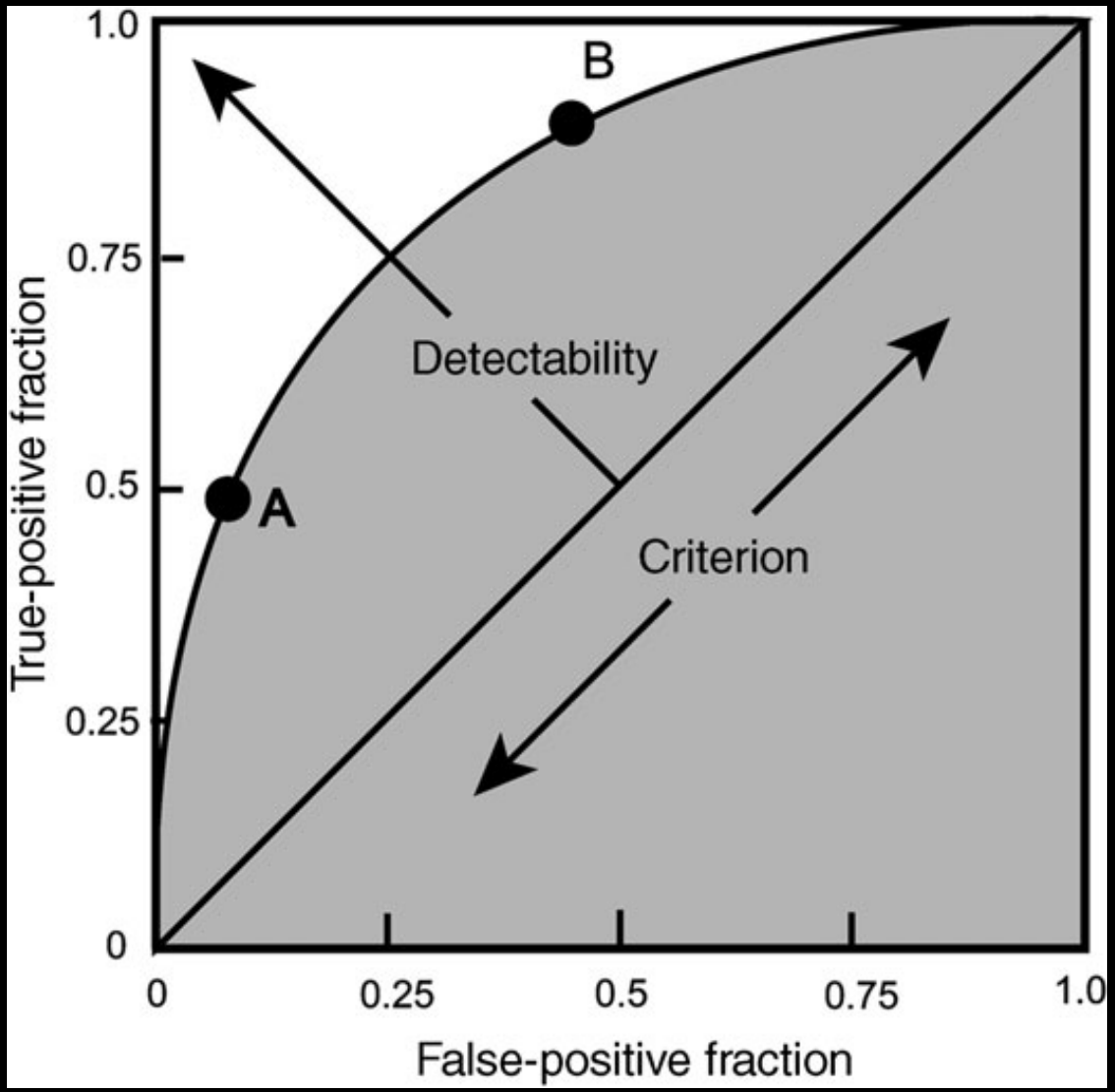
- **Patient specific QA has been viewed as a dosimetry problem.**
- **From dose point of view:**
  - **How different is the measured dose from the planned dose?**
  - **Detectors, spatial resolution, etc.**
- **From image analysis point of view:**
  - **Is the measured beam fluence abnormal?**

From a statistics point of view

- **Statistical tools exist to measure how different two (1-dimensional) distributions are.**
- **Extended to 2-dimensions, this problem becomes very difficult to solve explicitly.**
- **Measures of dose difference at a point and distance to agreement:**
  - **indicate conformance,**
  - **difficult to generalize**

Decision Theory

- **The ROC Decision model**
  - **Receiver Operator Curve (ROC) is a plot of performance of a binary classifier system.**
- **Graphical tool allows quantification of best cut-off point.**
- **Also offers insight into where gains in sensitivity and specificity can be obtained.**


1.0
0.75
0.5
0.25
0
True-positive fraction
B
A
Detectability
Criterion
0
0.25
0.5
0.75
1.0
False-positive fraction

Generalizing IMRT QA results

- **Evidence that IMRT/VMAT QA results don't translate well center to center.**
- **Letourneau, McNiven & Jaffray (IJROBP 2013)**
  - **Multi-institutional evaluation of IMRT/VMAT QA.**
  - **Results depend on the performance of many variables.**
  - **Variables interact with each other in ways that can be non-intuitive.**
- **Different centers may report IMRT/VMAT QA results that are similar, but the performance of their systems may be different.**
  - **Leaf calibrations, beam models, etc.**

ROC analysis in patient specific quality assurance

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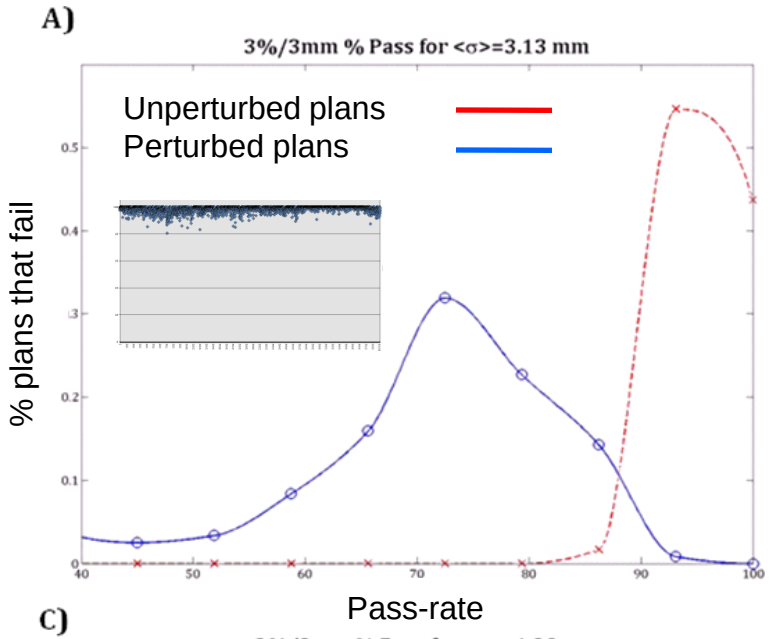
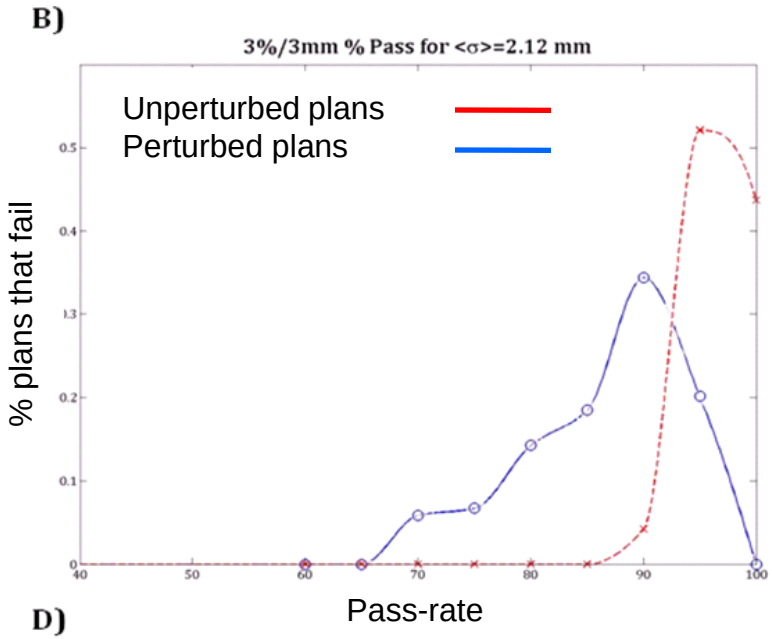
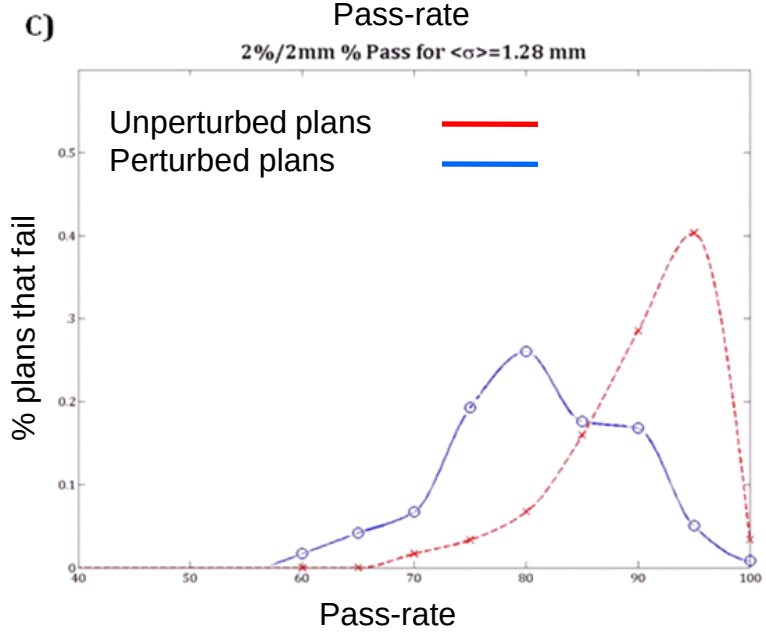
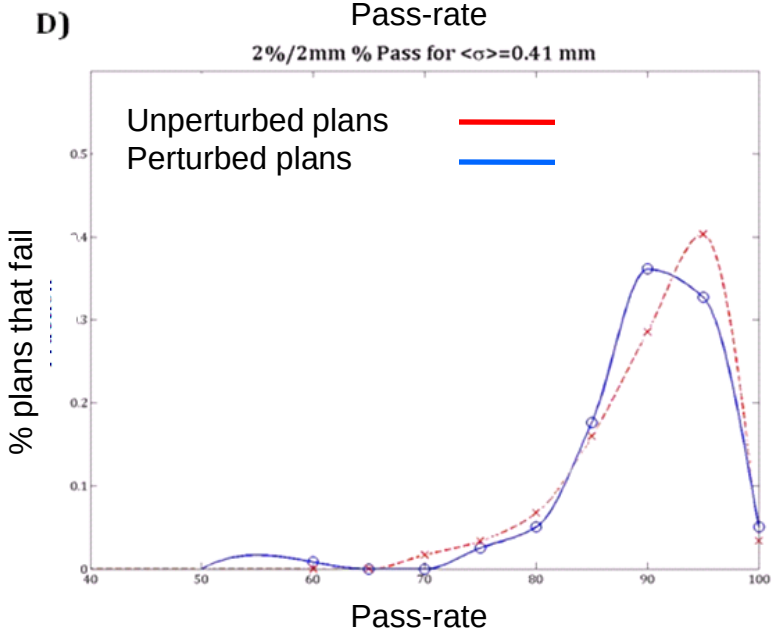
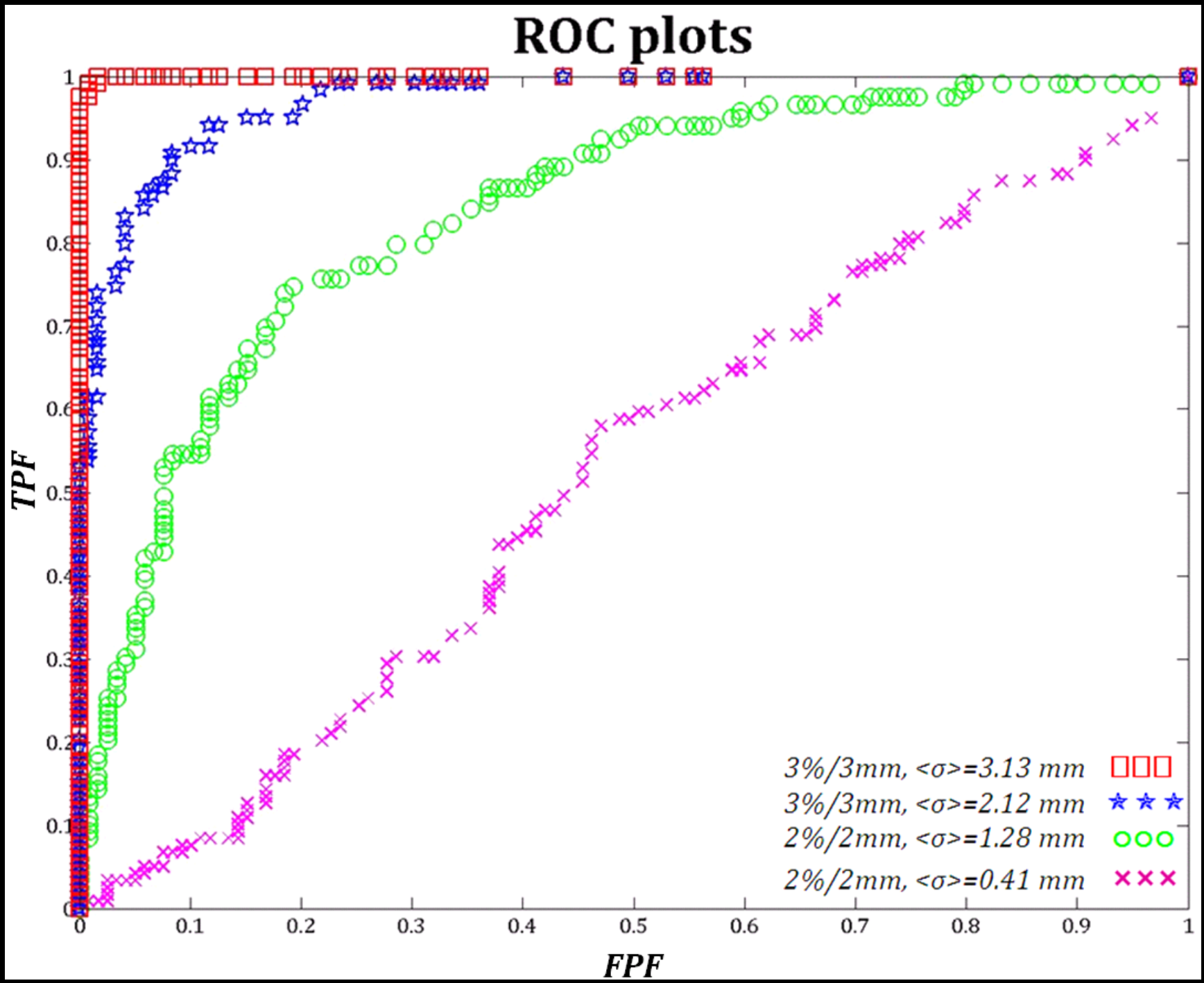
- 34 patients (single phase prostate cases)
- Half delivered normally.
- Other half delivered with known MLC errors
  - 1 mm, 2 mm, 3 mm
- Assume that the unperturbed delivery was “true” fluence pattern.
- Depending on passing criterion, measure rates of TP, TN, FP, FN.


A)
3%/3mm % Pass for <σ>=3.13 mm
Unperturbed plans
Perturbed plans
% plans that fail
Pass-rate

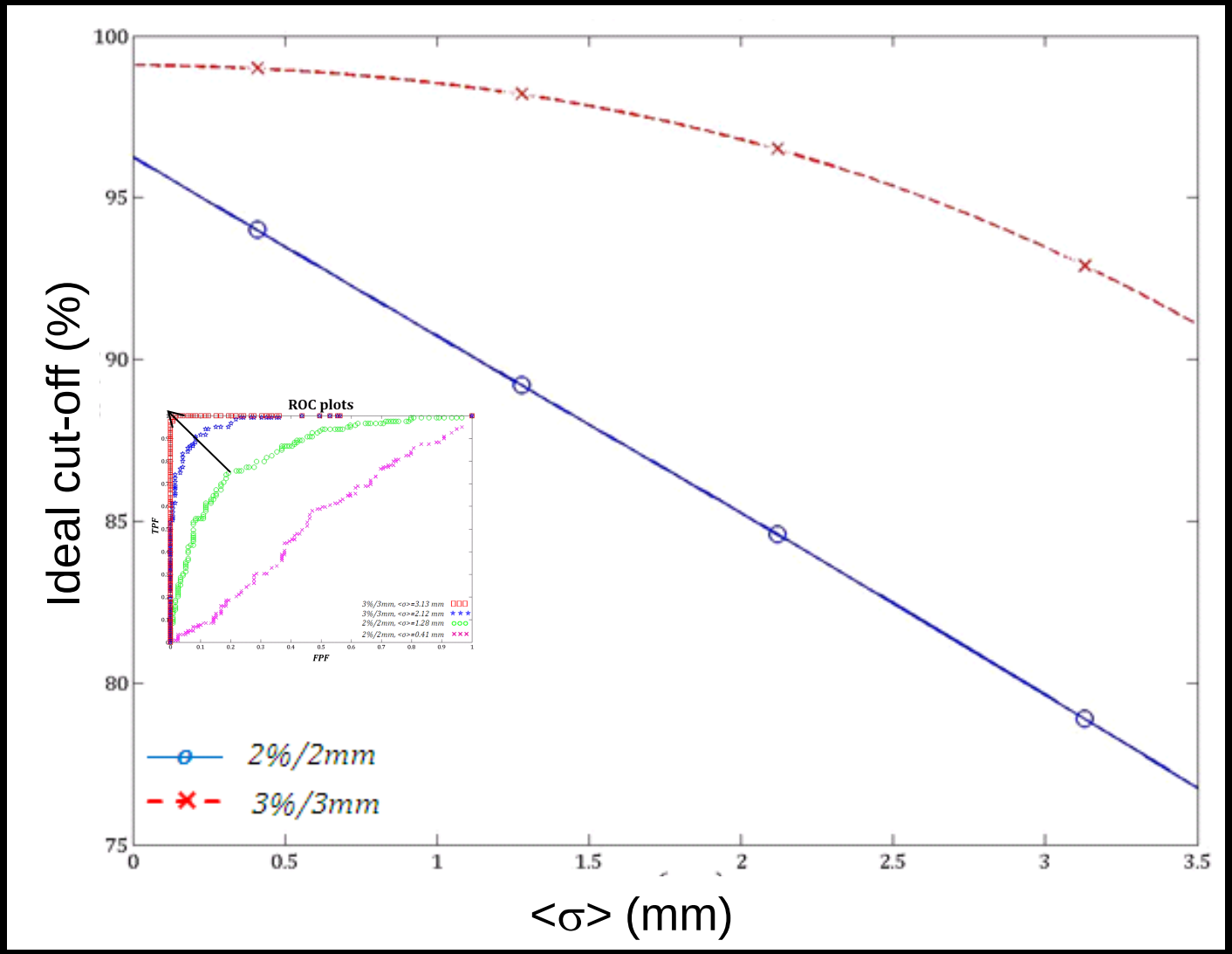

B)
3%/3mm % Pass for <σ>=2.12 mm
Unperturbed plans
Perturbed plans
% plans that fail
Pass-rate


C)
2%/2mm % Pass for <σ>=1.28 mm
Unperturbed plans
Perturbed plans
% plans that fail
Pass-rate

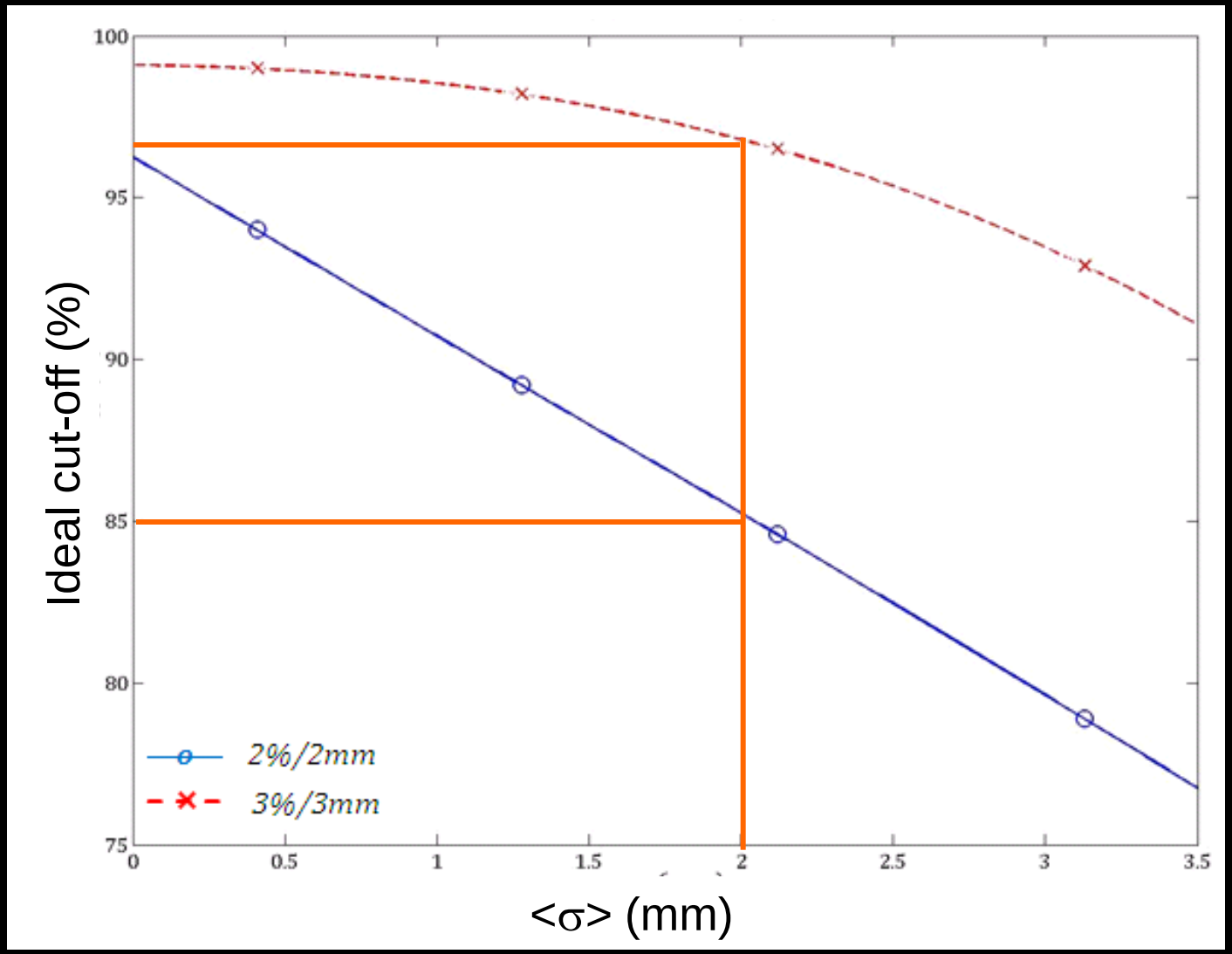

D)
2%/2mm % Pass for <σ>=0.41 mm
Unperturbed plans
Perturbed plans
% plans that fail
Pass-rate


ROC plots
TPF
FPF
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
3%/3mm, <σ>=3.13 mm
3%/3mm, <σ>=2.12 mm
2%/2mm, <σ>=1.28 mm
2%/2mm, <σ>=0.41 mm

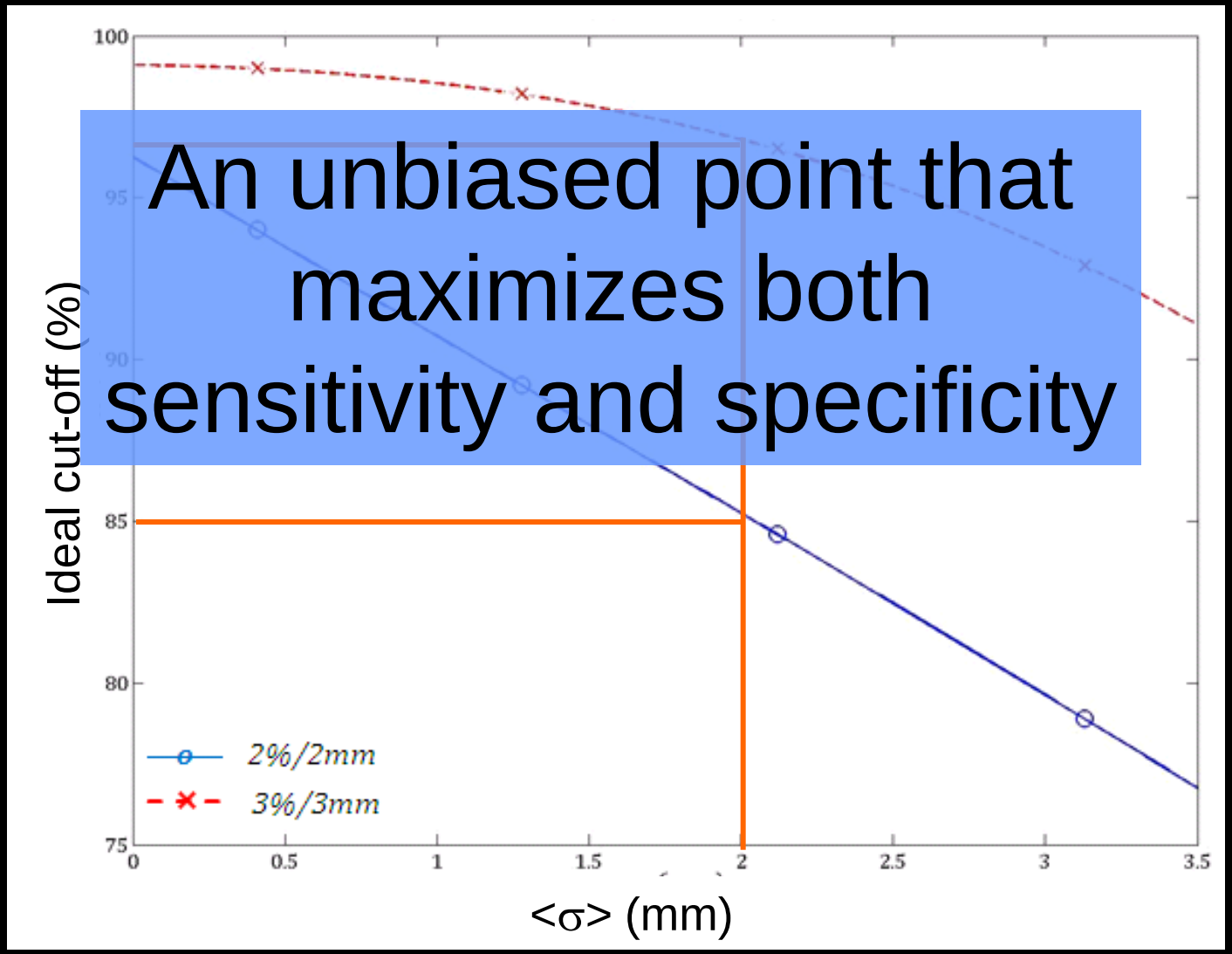
Setting the detector's operating point



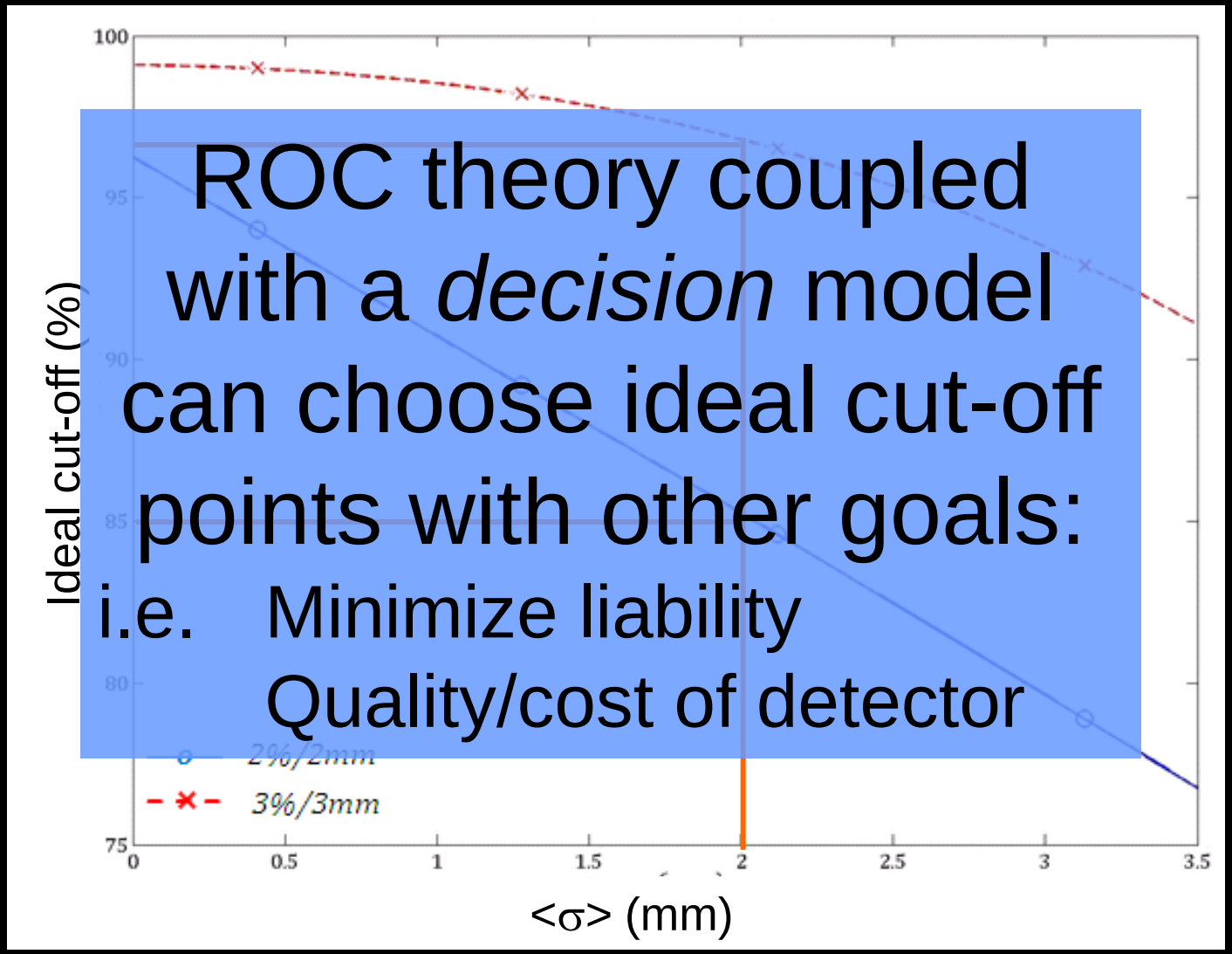
Setting the detector's operating point



Setting the detector's operating point



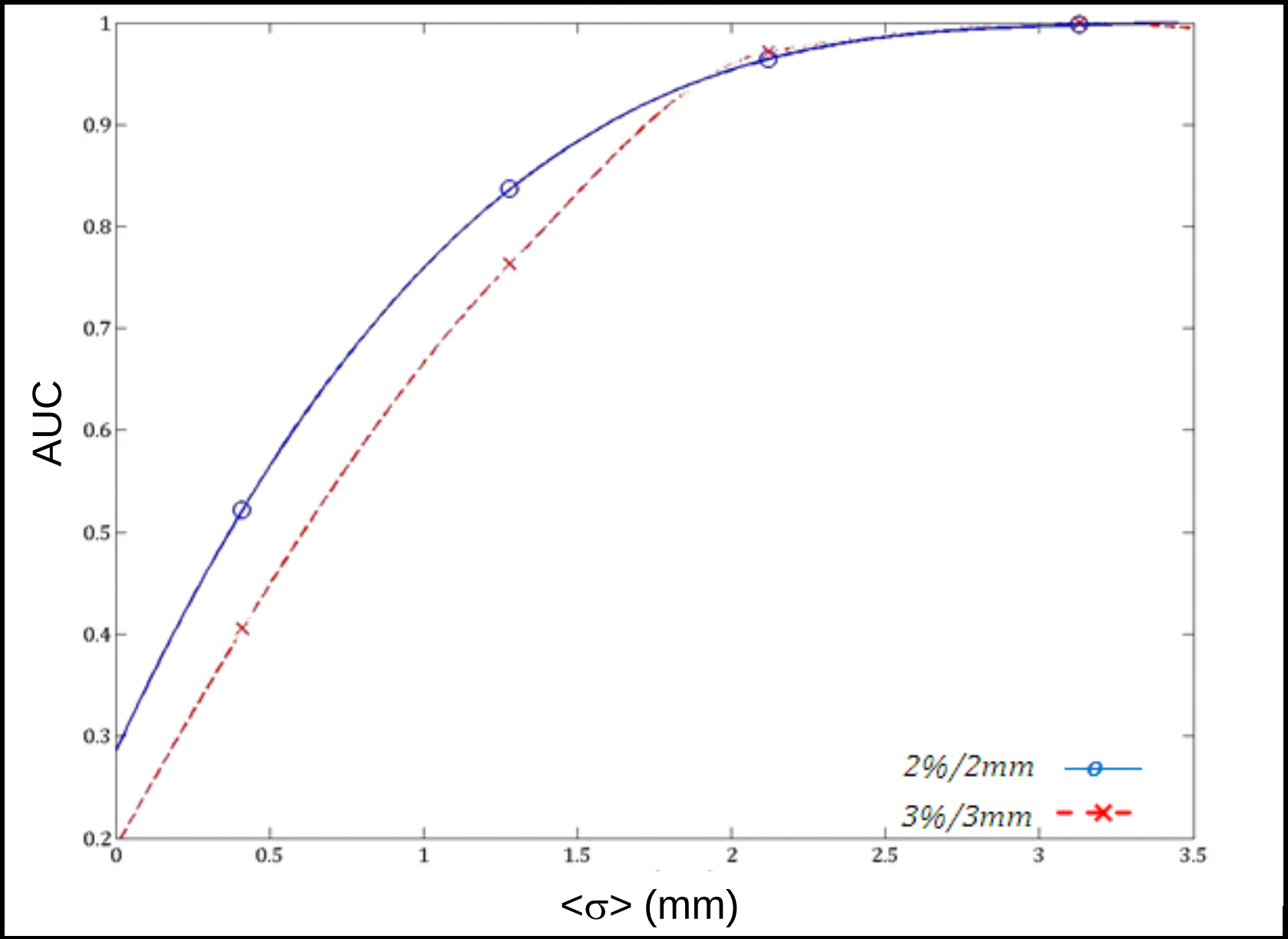
Setting the detector's operating point

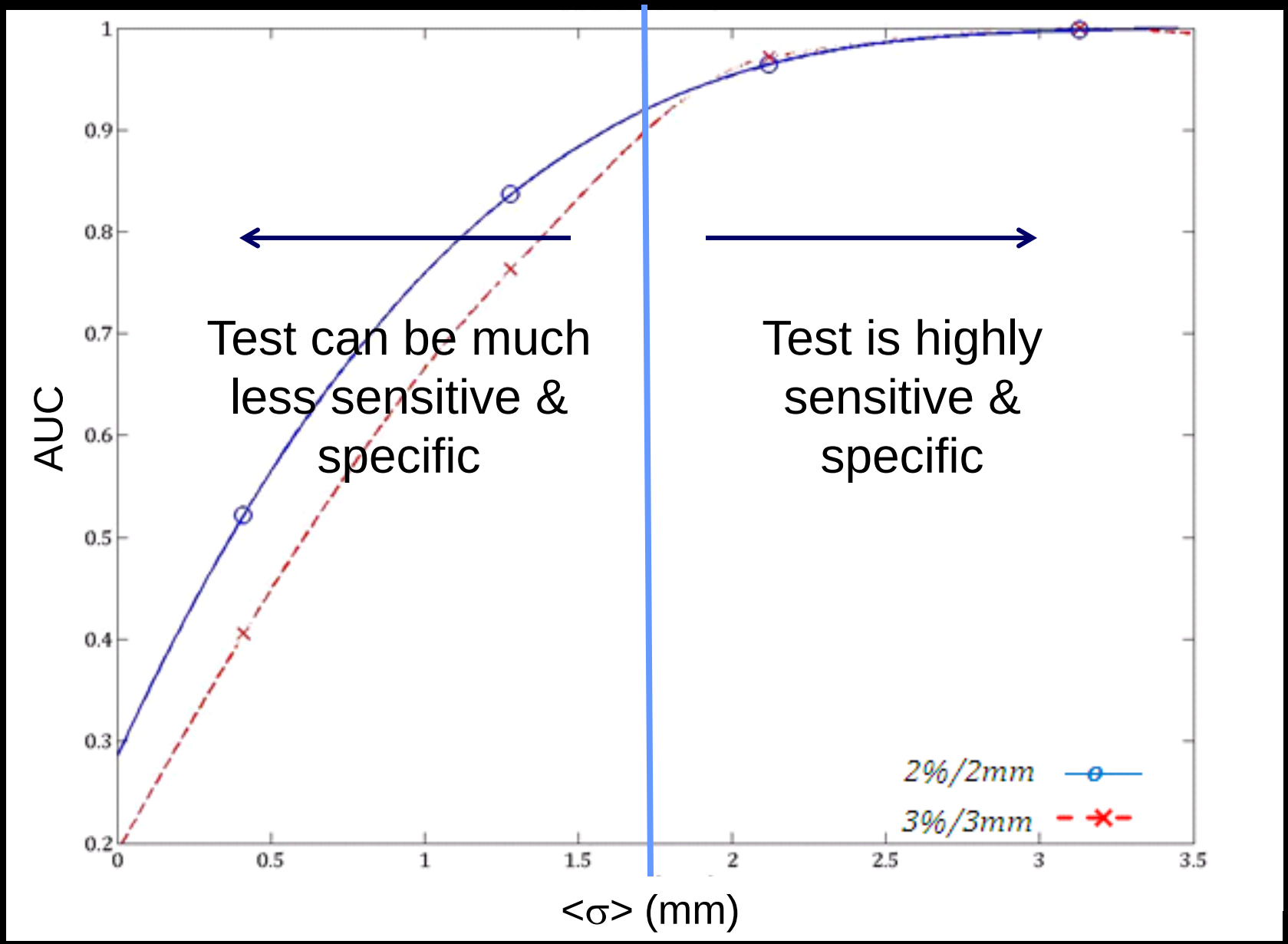


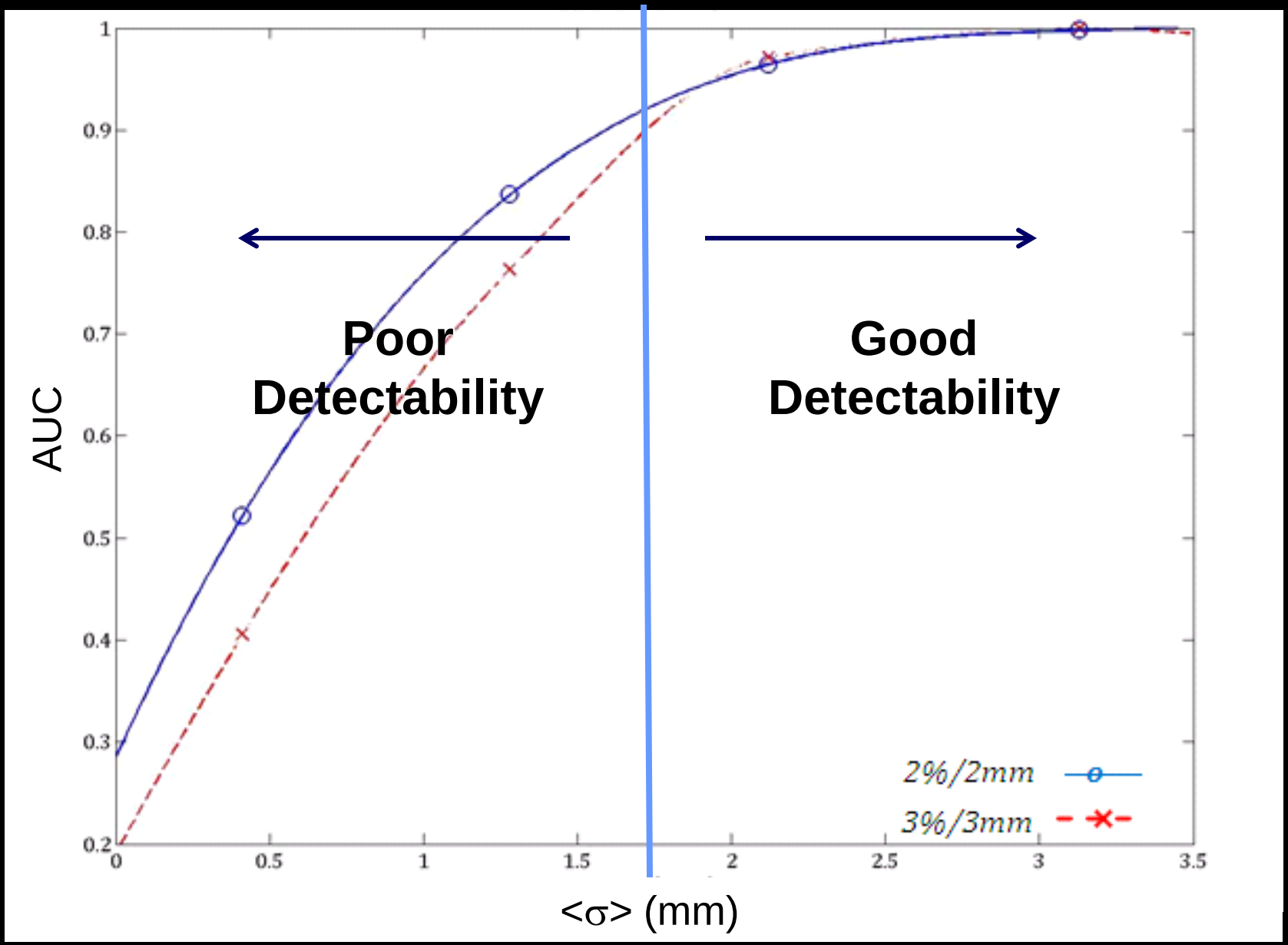
ROC theory coupled with a *decision* model can choose ideal cut-off points with other goals:

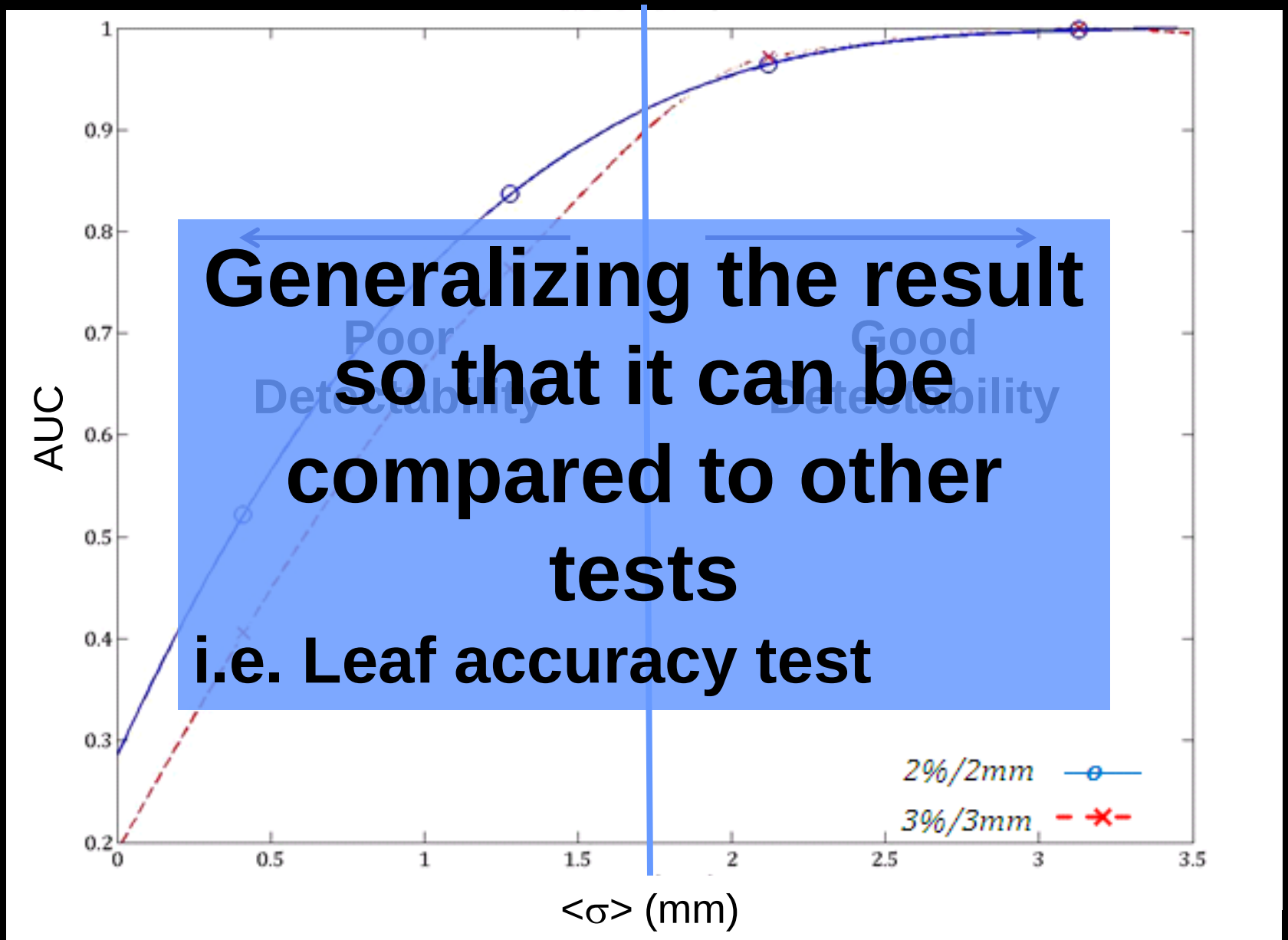
i.e. Minimize liability

Quality/cost of detector


AUC
<σ> (mm)
2%/2mm
3%/3mm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.5
1
1.5
2
2.5
3
3.5


AUC
<σ> (mm)
Test can be much less sensitive & specific
Test is highly sensitive & specific
2%/2mm
3%/3mm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.5
1
1.5
2
2.5
3
3.5


AUC
<σ> (mm)
Poor
Detectability
Good
Detectability
2%/2mm
3%/3mm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.5
1
1.5
2
2.5
3
3.5



Generalizing the result so that it can be compared to other tests

i.e. Leaf accuracy test

The problem with γ

- **“Gamma” is not a physical measurement, nor does it have statistical meaning.**
- **It has local significance, but it is difficult to interpret in a broad, multi-institution sense.**
- **It’s interpretation will always be controversial.**

Summary

- **QA activities are meant to help a specific local problem.**
- **Local problems are often relevant with a ‘narrow’ set of constraining factors.**
- **For the knowledge gained from these activities to be helpful in a broad sense, efforts can be made to choose metrics that have a generalized context.**
- **In the example of patient specific QA, thinking of the problem from a ‘detectability’ point of view led to quantification of some parameter thresholds that may be helpful in more general problem solving.**