Measurement Protocols for Quantifying the Effects of Electrostatic Attraction on Microcontamination in a Semiconductor Fab

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Evaluating ESA Effects

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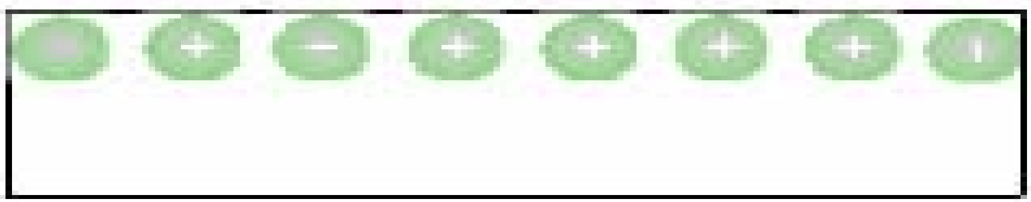
Charged Surfaces Attract Contaminants Strongly

- Is this significant?
- How does this effect yield?
- That is the purpose of this type of study

Problem: How To Dissipate Static Charge on an Insulator?

Solution: Make the Air Conductive



Air Ions neutralize surface charge by contact.

Simplification: ESA

- Can be “turned” on or off through via ionization
- Adequate amounts of appropriately placed ionization!

Measuring ESA

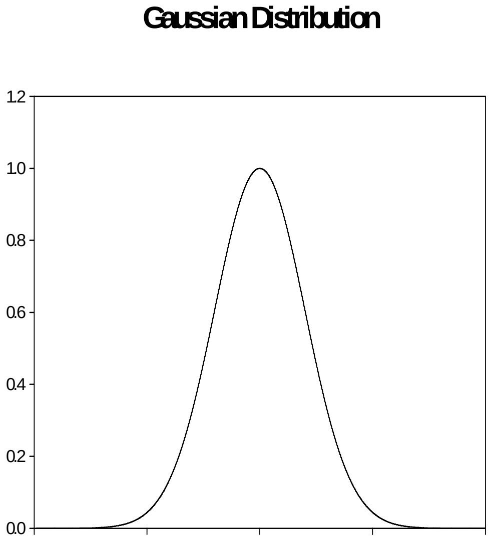
- Add ionization in tool where charge is created
- Measure particles added to wafer (PWP) by the process
- Turn on ionization
- Re-measure

Measurment Protocol and Statistics

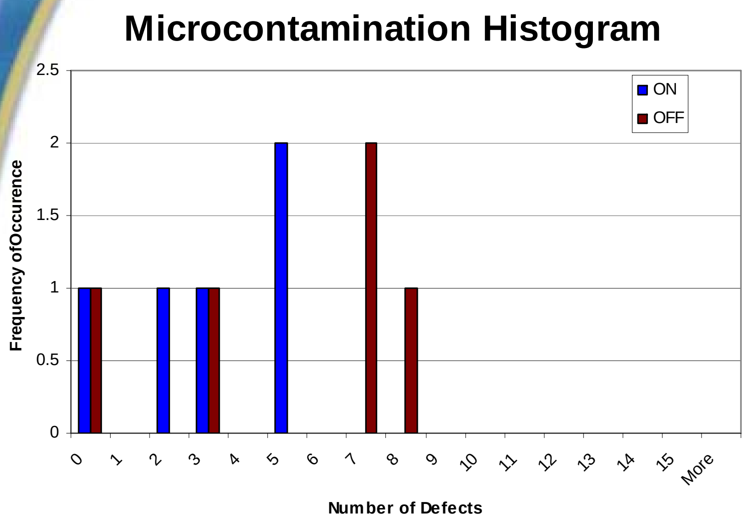
- **Each wafer has**
  - **an expected number of particles, N**
  - **a standard deviation, σ**
- **Measuring N on <u>one</u> wafer gives very little information**
- **Sufficient wafers are required to make σ $_{\text{mean}}$ sufficiently small.**

$$P_p(n|N) = \binom{N}{n} p^n q^{N-n}$$

$$\sigma^2_{mean} = \frac{\sigma^2_{distribution}}{N}$$



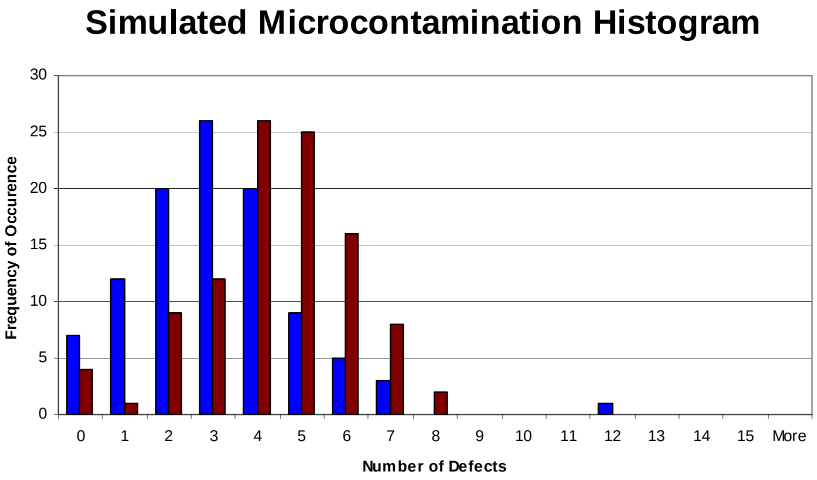
A 5 Wafer Simulation



PWP=4.5

PWP=3

150 Wafer Simulation

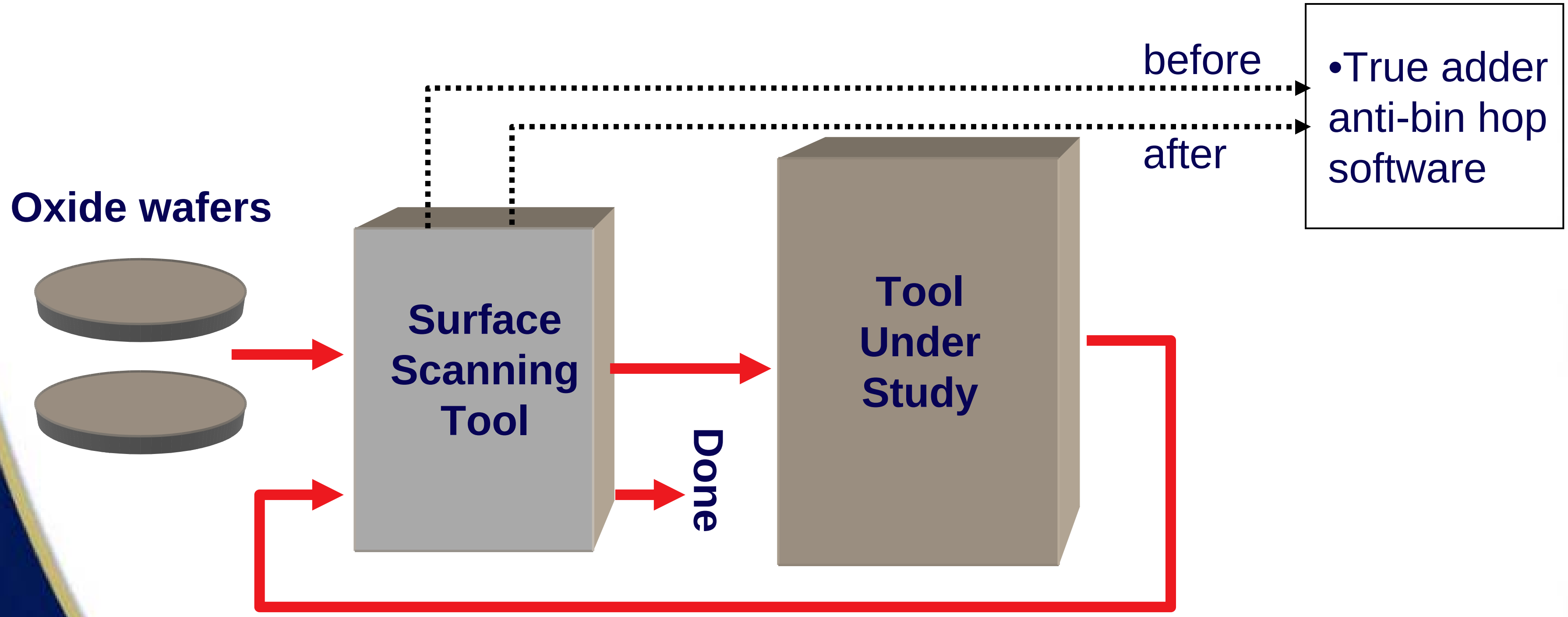


Measurement Scenerios:

- Use Scanned Results from Monitor Wafers
- Surface Scan Process Wafers
  - before and after the process, a special metrology requirement
- Perform a Process Protocol through the tool on Unpatterned Spectator Wafers
  - The protocol should mimic real processing

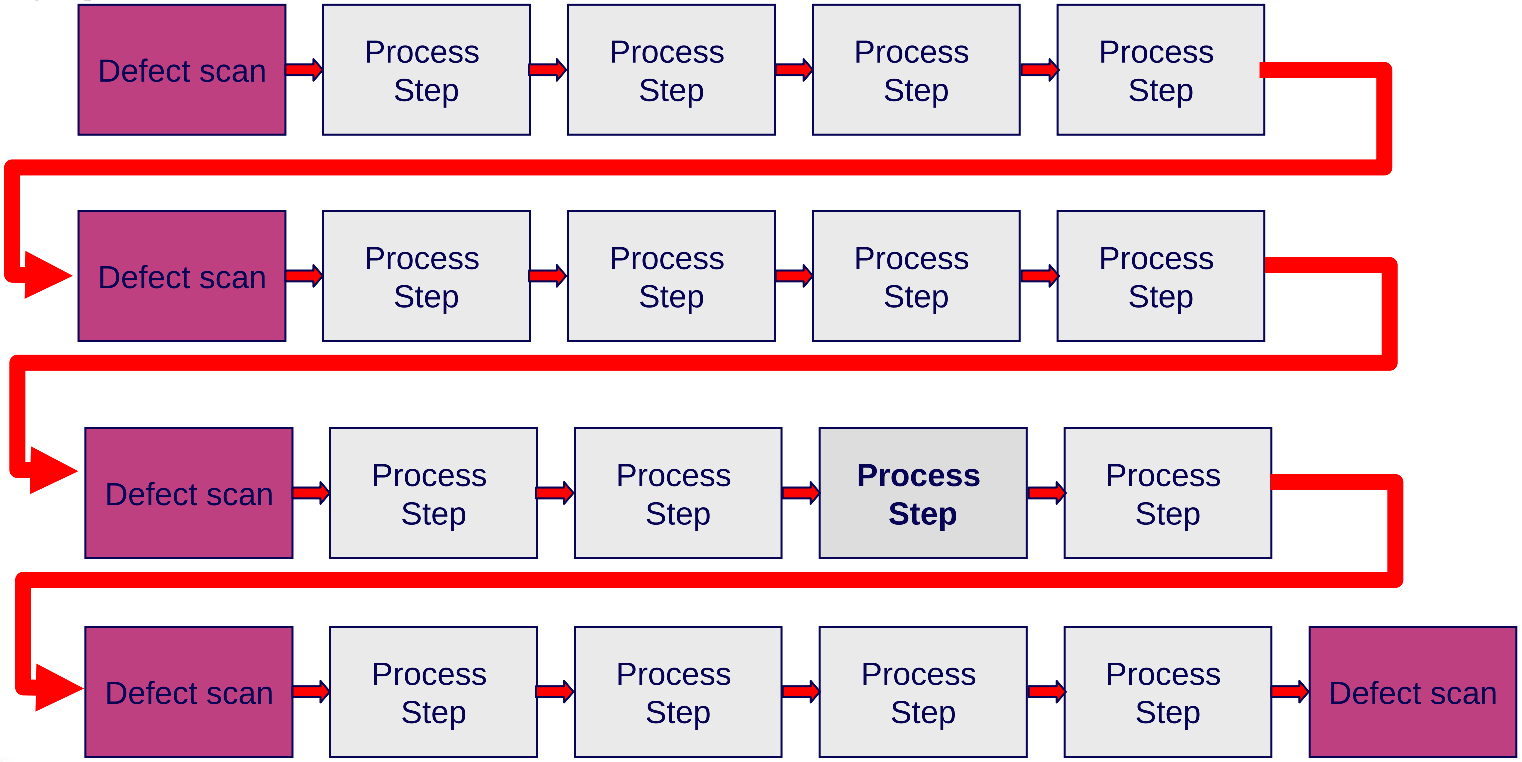
Monitor Wafer Scenerio

- Does not detract from fab operations
- Un-patterned wafers should be used
- Ideally, wafers should be oxide wafers to simulate the accumulations from processing (1-2 μm film)



Surface Scanning Process Wafer Scenerio

Typical Process Scenario



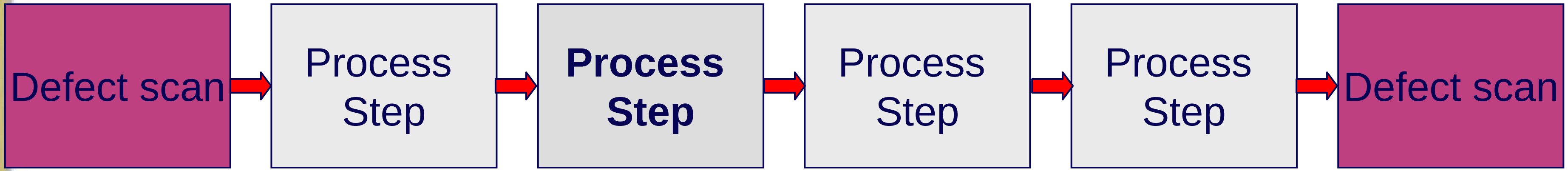
Defect scan → Process Step → Process Step → Process Step → Process Step

Defect scan → Process Step → Process Step → Process Step → Process Step

Defect scan → Process Step → Process Step → **Process Step** → Process Step

Defect scan → Process Step → Process Step → Process Step → Process Step → Defect scan

One Metrology Bound Process Segment


Defect scan

Process Step

Process Step

Process Step

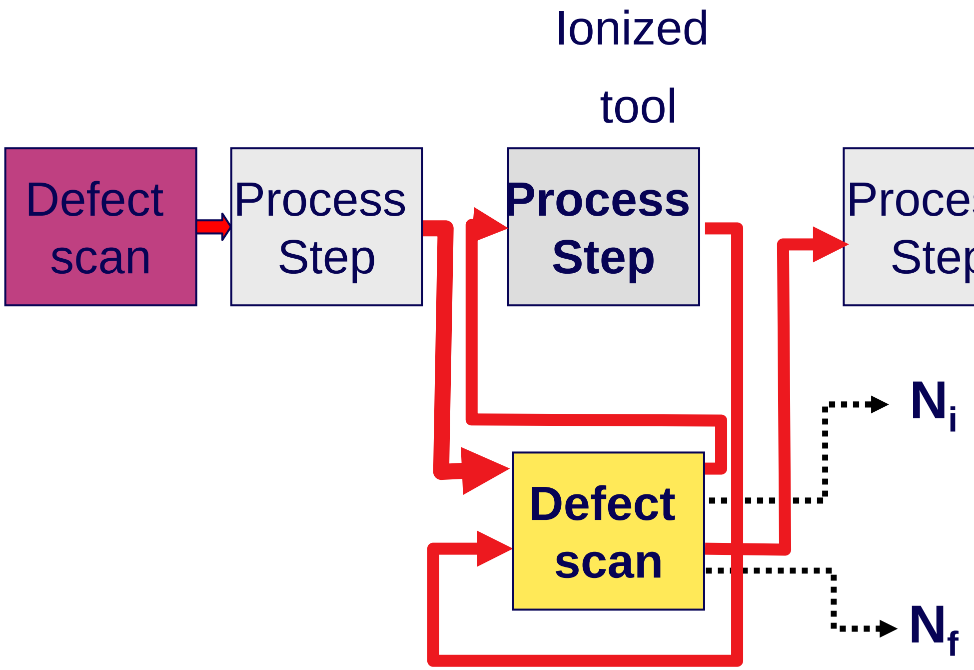
Process Step

Defect scan

N_i **N_f**

- This requires ionizing all of the tools of a given type
- Or obtain a route map per wafer,
  - Perform detailed multivariant analysis to isolate the effects of the ionized tools
  - Requires recoding the tool route for each wafer

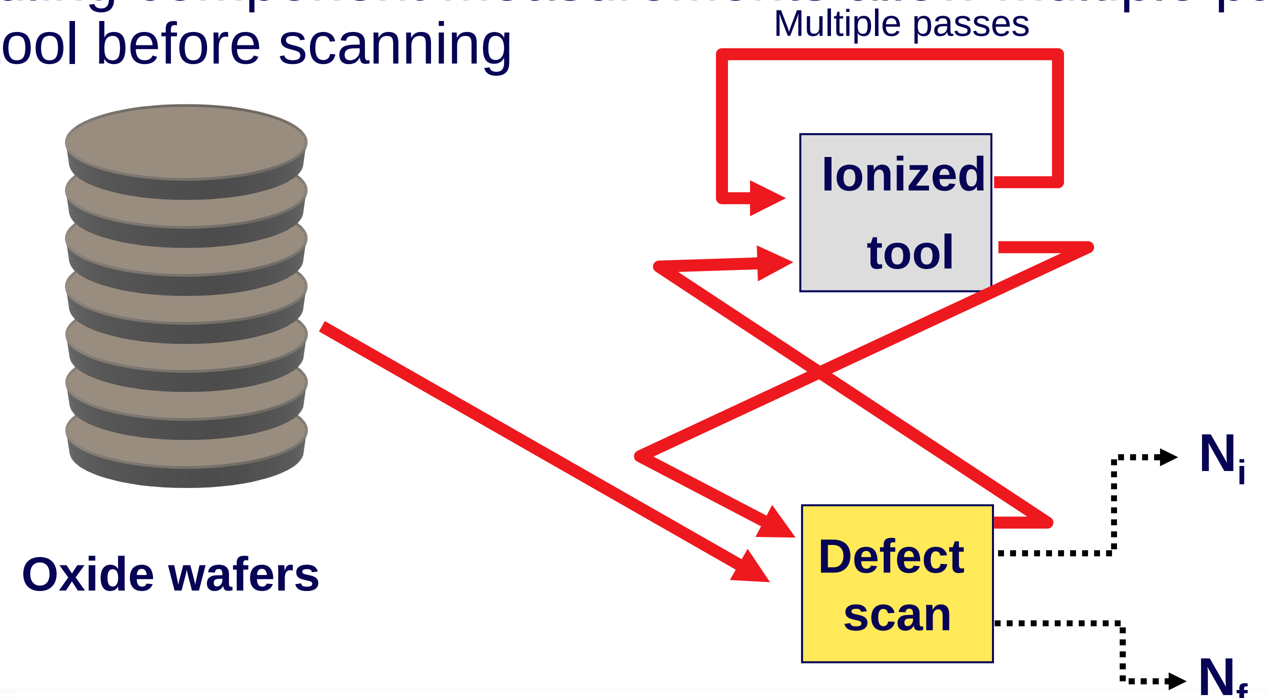
A Much Easier Topology to Analyze



- Requires additional metrology to run

Spectator Wafer Scenerio

- Often used as a handling component only study
- Most meaningful results involve oxide coated wafers ~ production wafers
- Can be done with process steps also but more thought is required t develop a meaningful test
- Handling component measurements allow multiple passes through the tool before scanning



Number of Defects Added

$$\Delta N = N_f - N_i$$

Allow for multiple wafers: ΔN_j= number defects on the j_{th} wafer

$$\overline{\Delta N} = \frac{1}{w}\sum_{m=1}^{m=w}\Delta N_m \quad ;N \text{ is } N^{on} \text{ or } N^{off}$$

Contamination Control Improvement

$$\overline{\Delta N}^{improvement} = \overline{\Delta N}^{off} - \overline{\Delta N}^{on}$$

Statistical Considerations

$$\overline{\Delta N}^{improvement} = \overline{\Delta N}^{improvement} \pm \sigma_{\overline{\Delta N}^{improvement}}$$

Experimental result is meaningful if

$$\overline{\Delta N}^{improvement} \geq 4\sigma_{\overline{\Delta N}^{improvement}}$$

Approximate binomial distribution by a Gaussian distribution

$$\sigma_{\Delta N} = \sqrt{\Delta N} \qquad \sigma_{\overline{\Delta N}} = \frac{\sigma_{\Delta N}}{\sqrt{w}}$$

Taking

$$N^{on} = 0.8N^{off}$$

(Detection threshold, a 20% improvement)

Solving for w:

$$w = \frac{718}{\sqrt{\Delta N^{off}}}$$

Example- Using this Relation

If the average number of defects in such a monitor is 5

321 Wafers with ions on and 321 wafers ions off are required

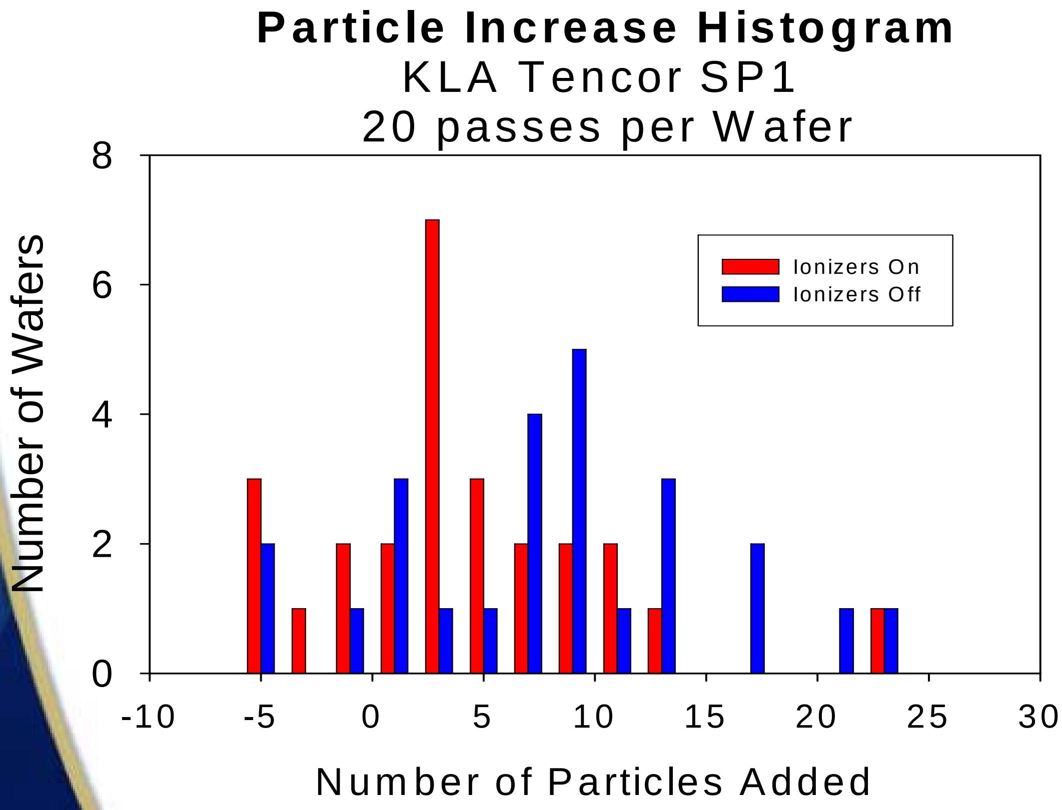
If there are 3000 wafer starts per week and 10% go through the tool set

3000*10%= 300 wafers/wk through the tool set

One week ions on, One week ions off

Histogram Of The Distribution Of Particles Added Per Wafer For 20 Passes.

Handling only


Particle Increase Histogram
KLA Tencor SP1
20 passes per Wafer

Condition	PWP		Standard Error
Ionization on	**0.245**	±	**0.046**
Ionization off	**0.455**	±	**0.058**

Monitor Wafer Results

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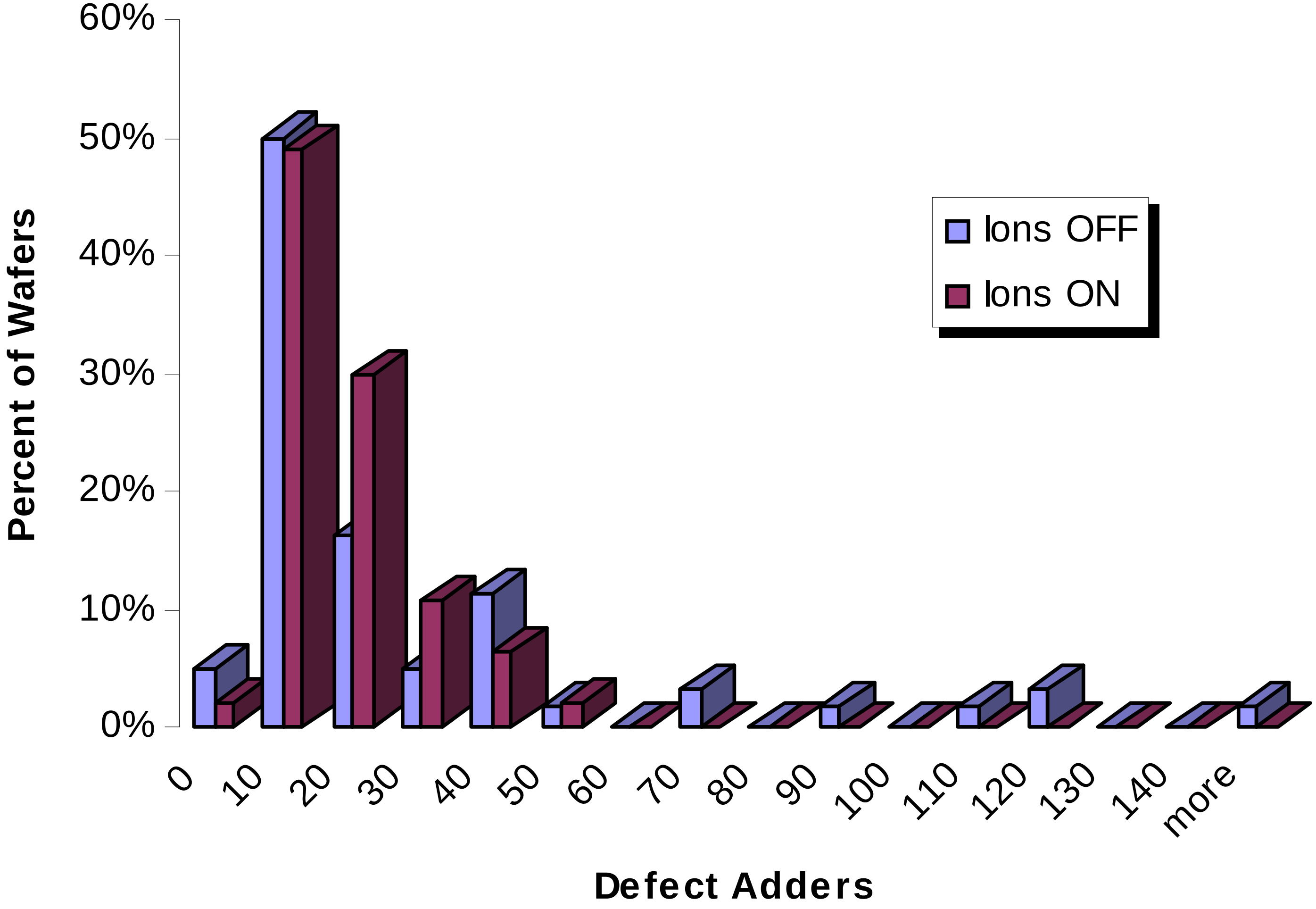
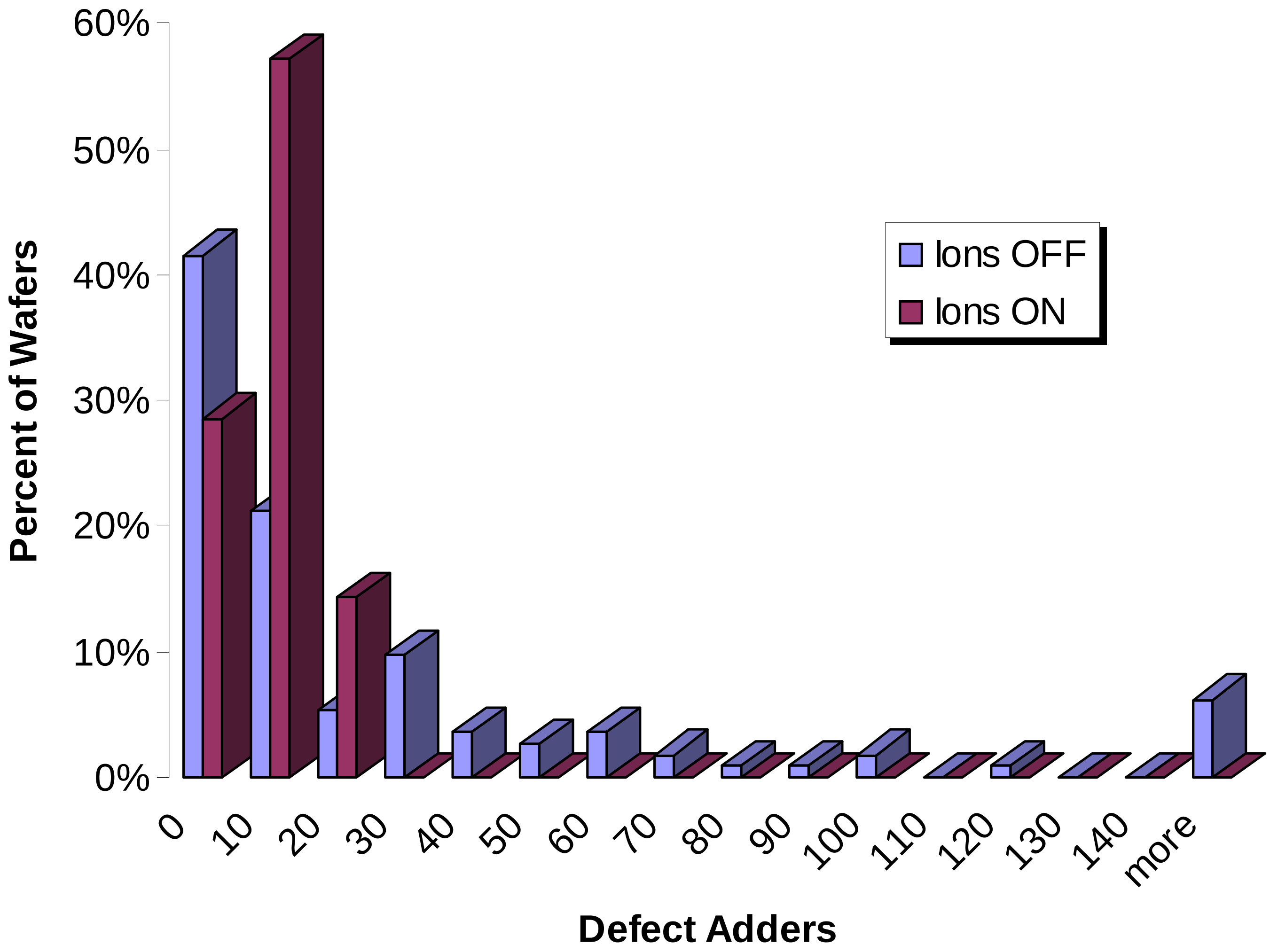
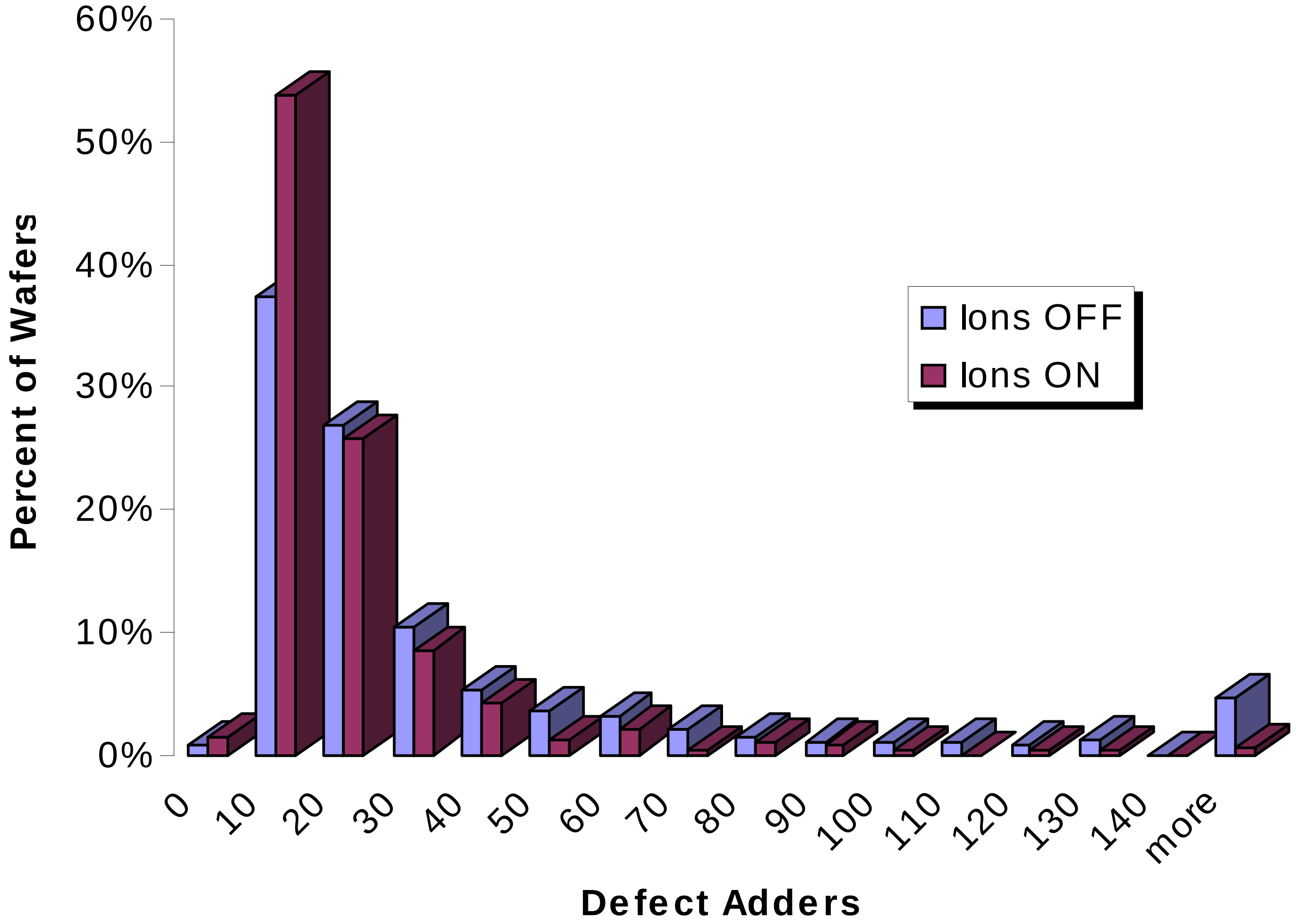
PVD Tool Results



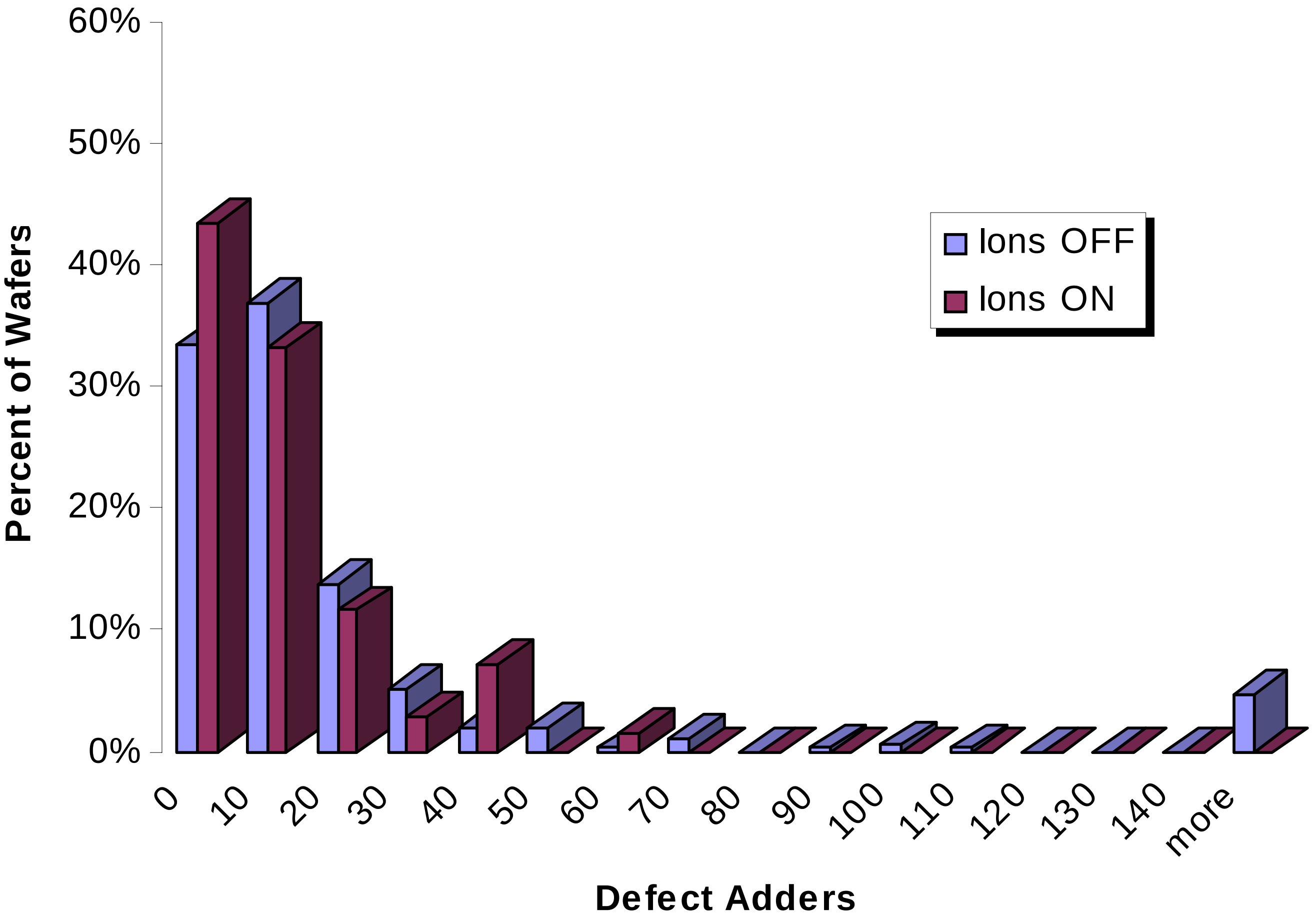
XRF Tool Results



Etch A Results



Etch B Results



Summary

- Pick your technique
- Estimate Number of particles expected
- Calculate minimum number of wafers required
- Design out systematic errors
- Run experiment
- Reduce Data

Evaluating Emitter Point Design

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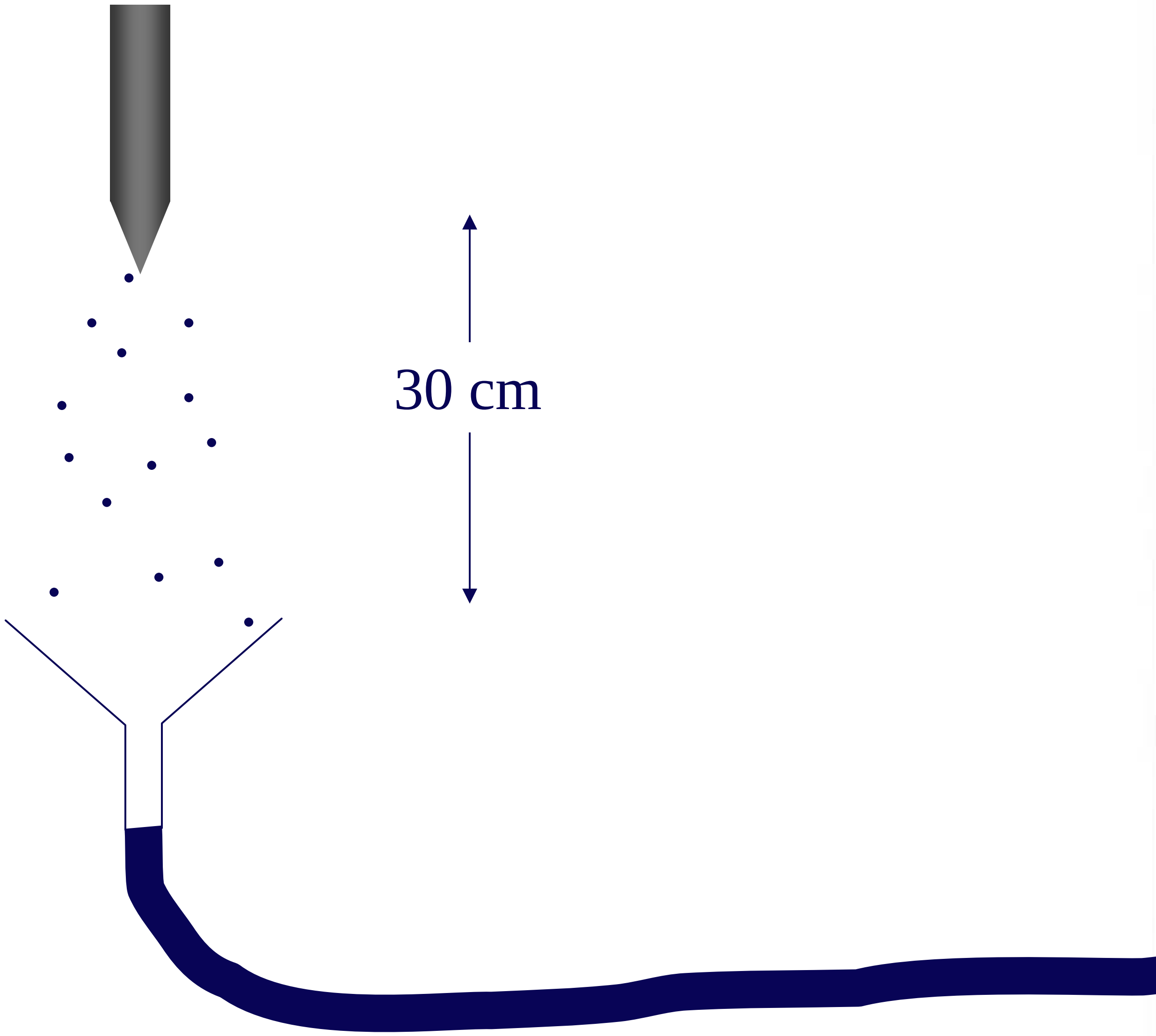
Emitter Points Shed & Particulate



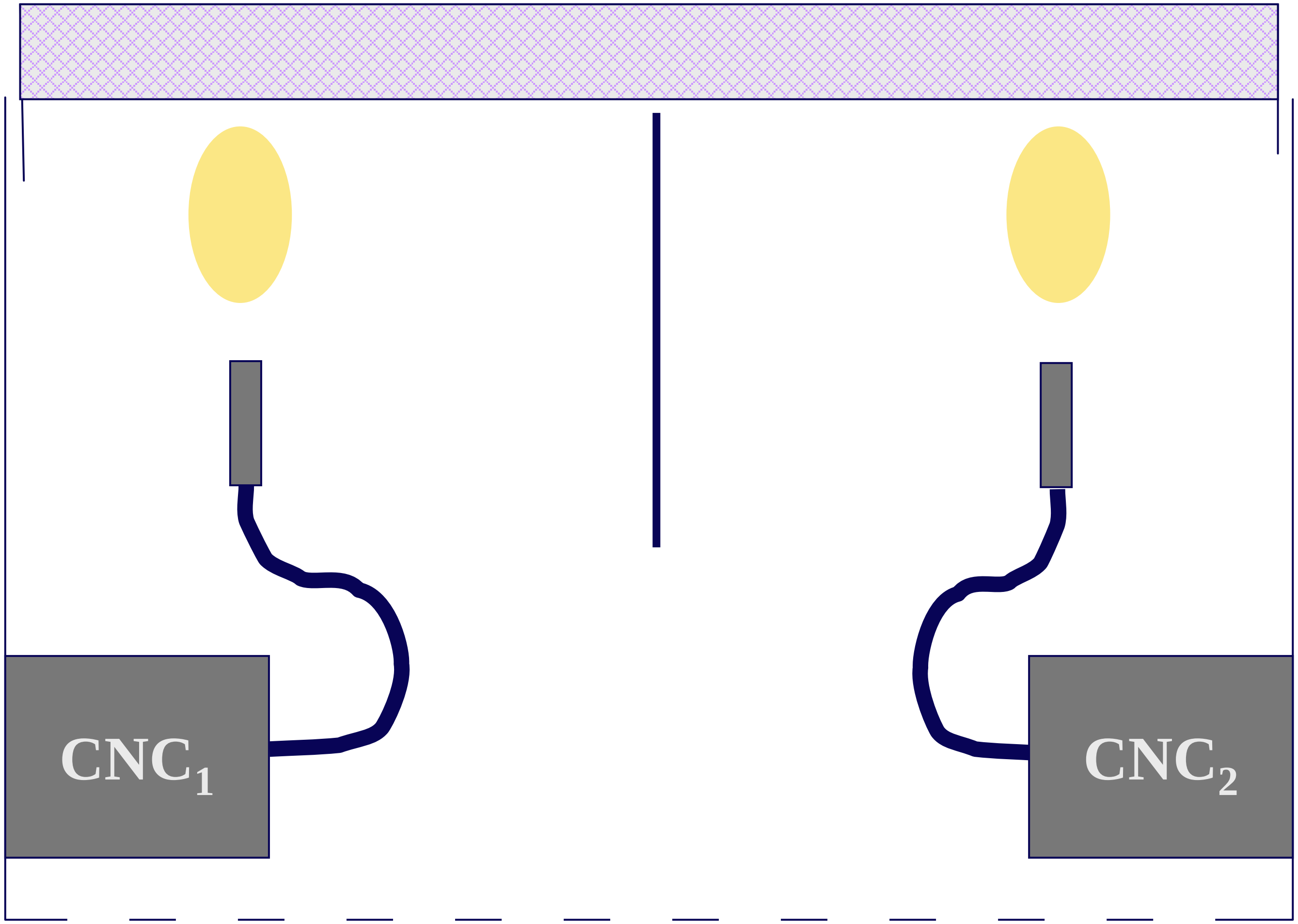
All Particles are < 100 nm

- Use Only a Condensation Nucleus Counter.
- A Laser Particle Counter Will Read 0 Particles.
- Calibration and stability of the CNC must be accounted for.

Exact Results are Highly Airflow Dependent

- Location in the Test Chamber is a Factor
- Materials in the Chamber are Factors
- Airflow in the Chamber is a Factor

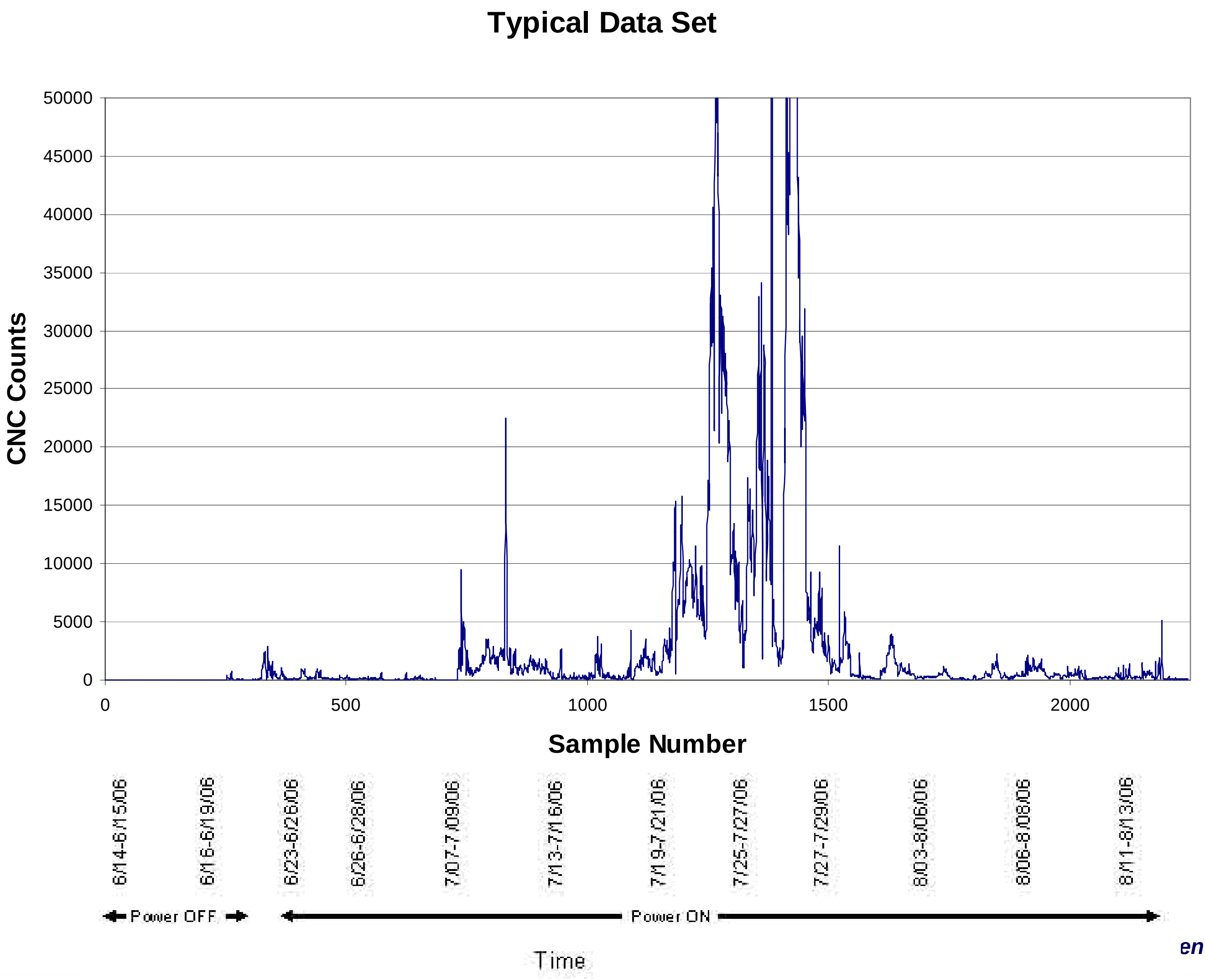
There are Systematic Errors to Design Out



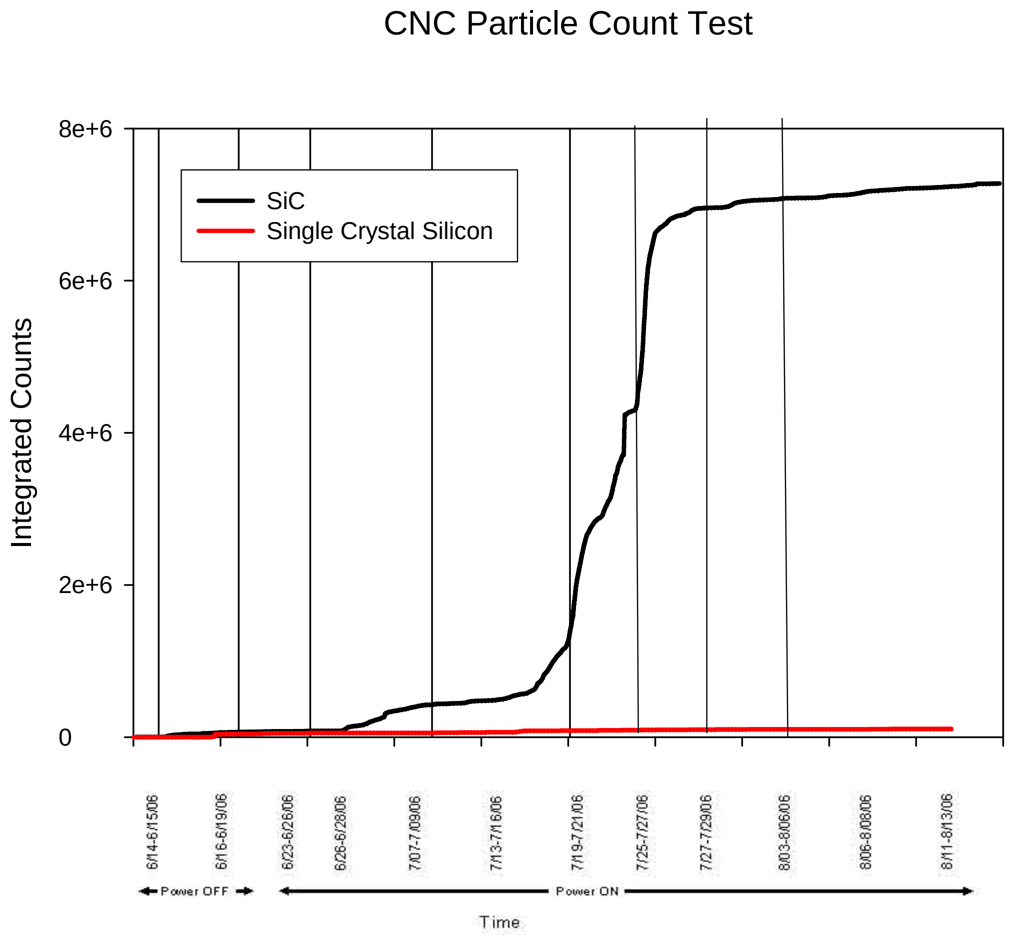
Variation of the Parameters to Eliminate Systematic Errors

CNC 1	CNC 2	Position 1	Positon 2
Si	SiC	Si	SiC
SiC	Si	Si	SiC
Si	SiC	SiC	Si
SiC	Si	SiC	Si
Si	SiC	Si	SiC
SiC	Si	Si	SiC
Si	SiC	SiC	Si
SiC	Si	SiC	Si

Typical Dataset Has Huge Fluctuations



Solution to Fluctuations – Integrate: Display Summed Counts



Conclusions

- Different emitters do have different particle levels
- Particles from ionizers are <<100 nm
- Integrated particle counts display the differences
- It is possible to account for and correct for systematic errors.

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