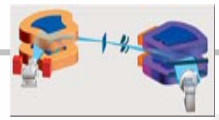


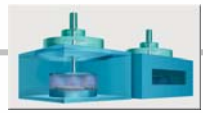

# Plasma Doping (PLAD) for Advanced USJ Applications

West Coast Junction Technology Group Meeting
14-July-2005

S. Walther, L. Godet, T. Büyüklimanli, J. Weeman
R. Liebert, & P. Nunan

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# PLAD for Advanced USJ Outline

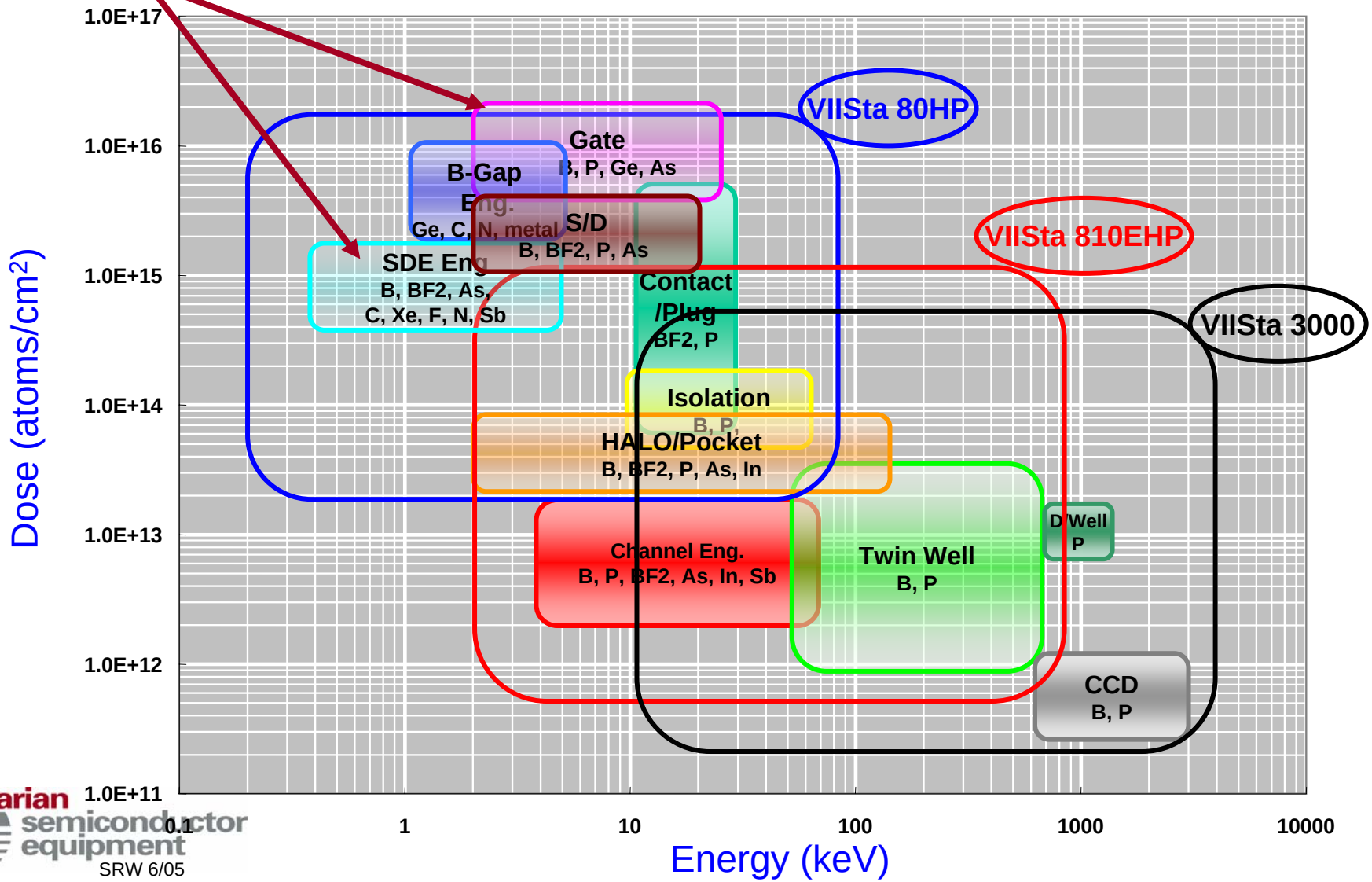
- Introduction
- USJ dopant depth profile comparison to beamline
  - Plasma implant mass/energy diagnostic
- Profile accuracy & repeatability
  - USJ regime
- Timing effects
  - Plasma pulse vs. wafer bias timing
- Summary

# PLAD Introduction

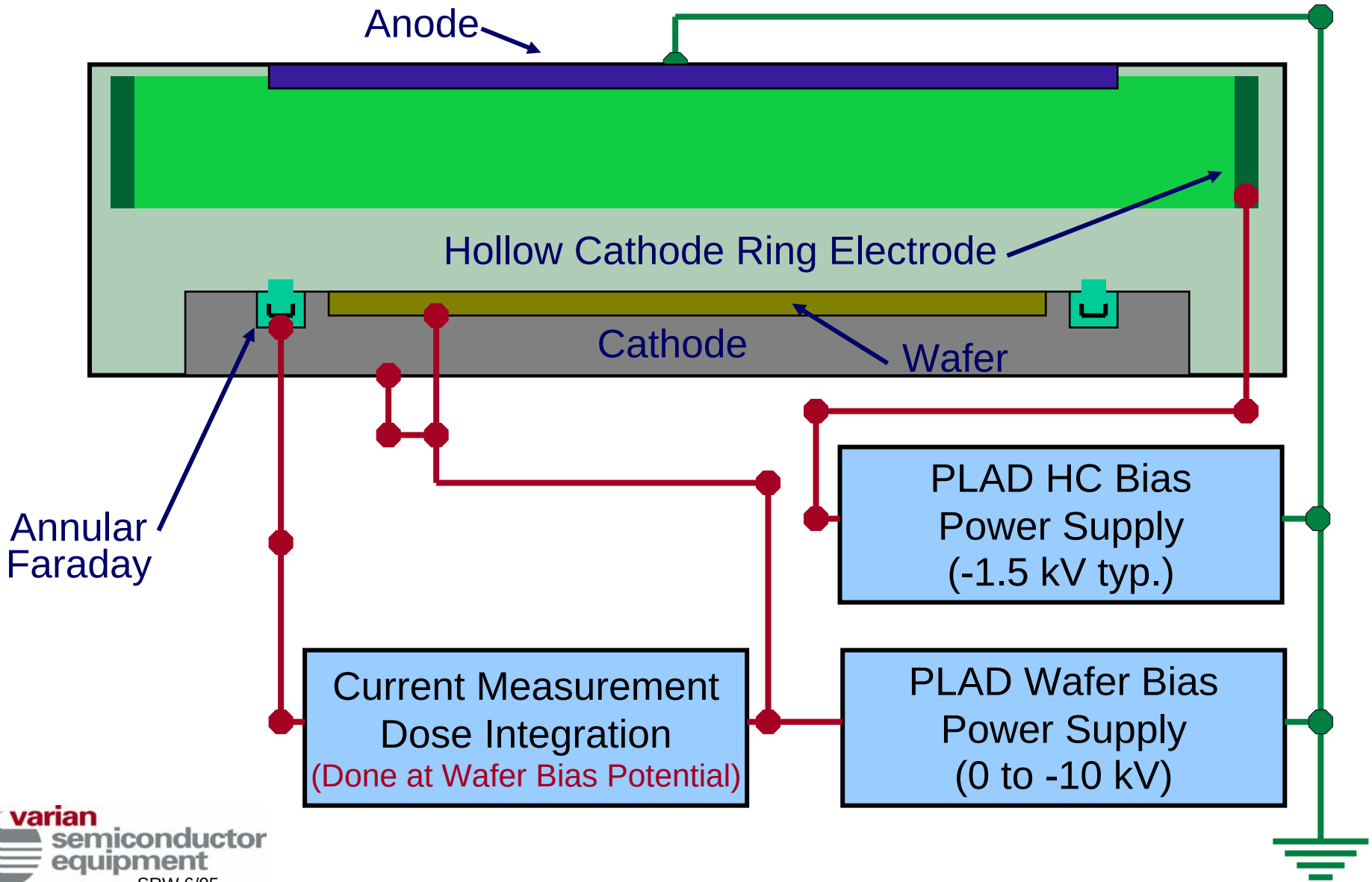
- How it works
  - Plasma is created adjacent to the wafer
  - Wafer is biased to the desired potential
  - Bias accelerates ions across a plasma sheath
    - Bias is pulsed and repeated at a high frequency
    - Dose is counted for each pulse
    - When the desired dose value is reached, pulsing stops
- Unique features
  - No mass selection
  - Entire wafer is implanted at high dose rate

# Doping Applications Space

**High current implants: doses increasing, energies decreasing, 0˚**



# Plasma Implant System



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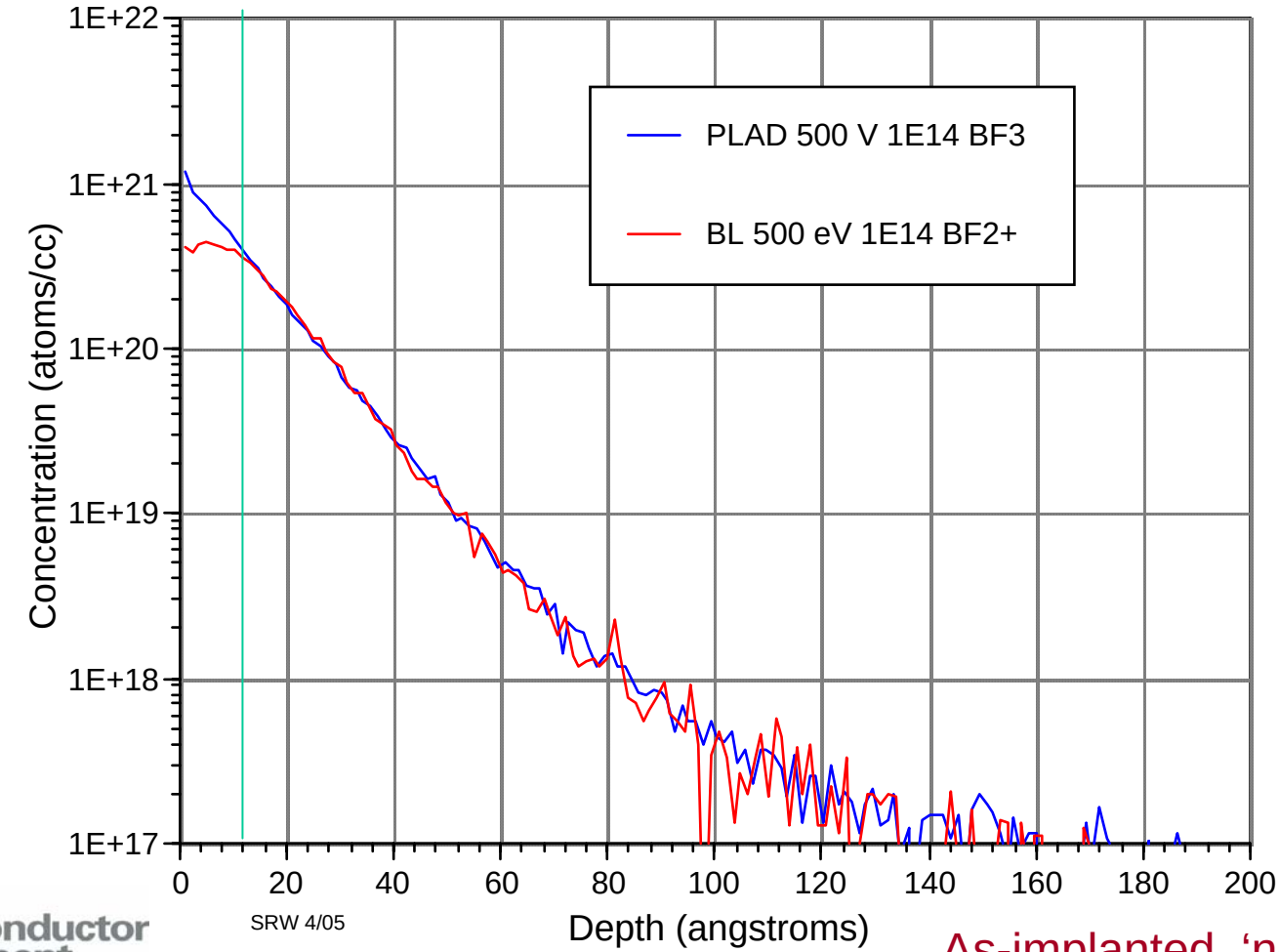
# PLAD vs. Beamline Boron Depth Profiles

## 500 V 1E14 $BF_3$ vs. 500 eV 1E14 $BF_2^+$

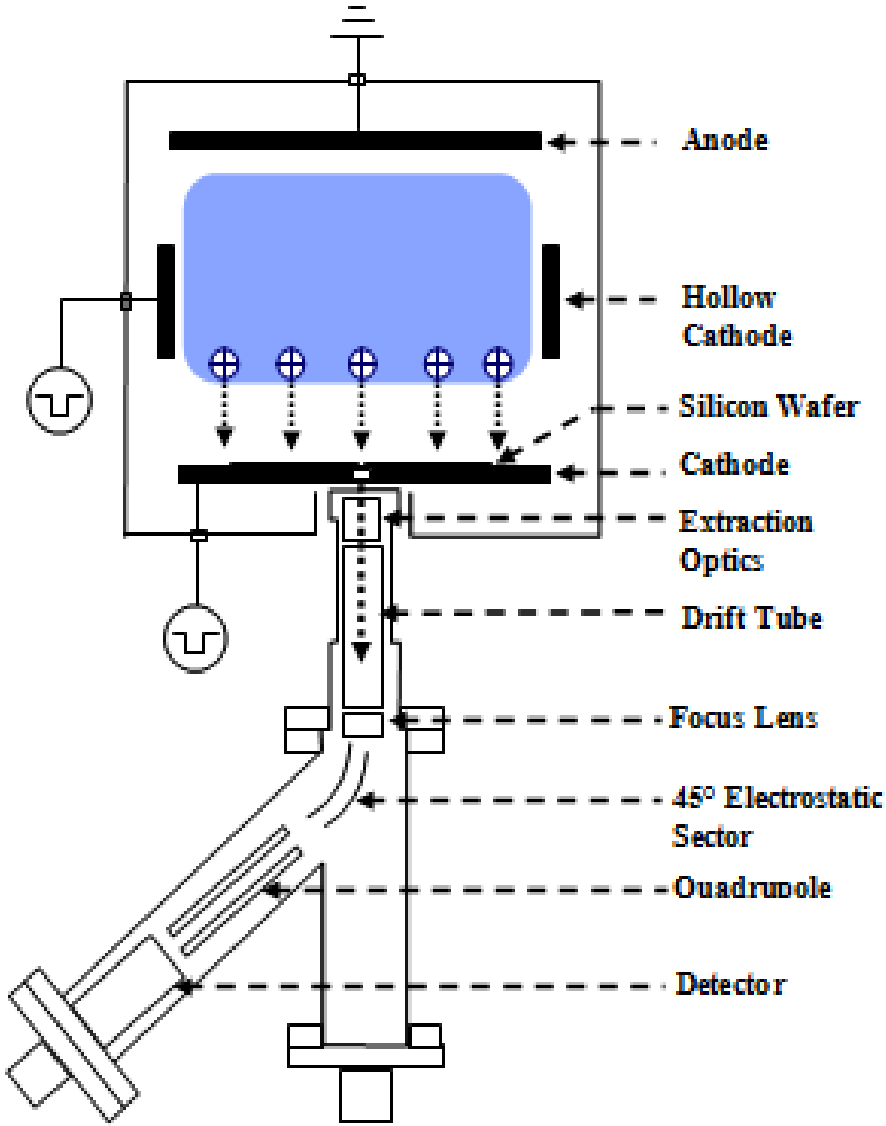
Matched profiles imply similar ion mass/energy

1.2nm RTO



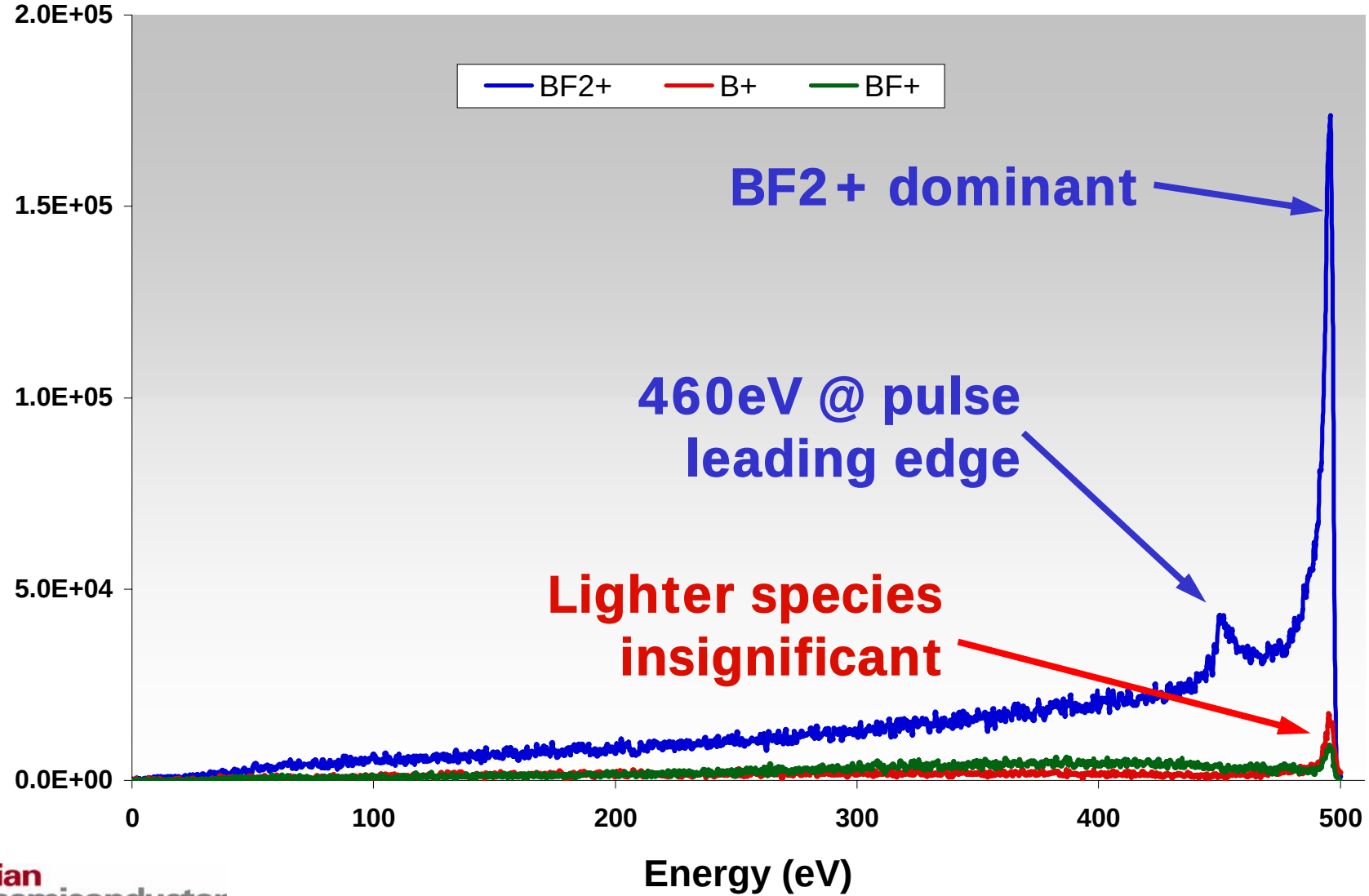

As-implanted, 'no-leak' SIMS

# Mass/Energy Spectrum Diagnostic



# Ion Mass and Energy Spectrum

## 500 V $BF_3$ Plasma Implant

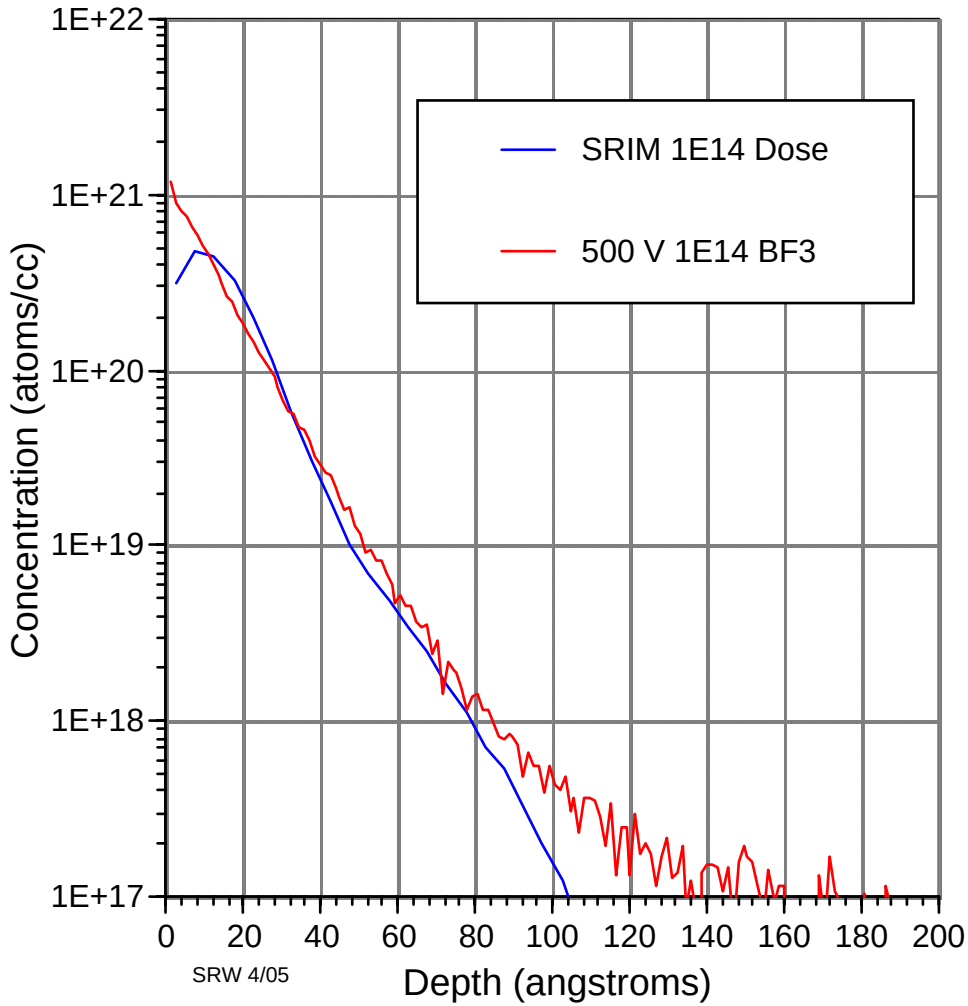


# SRIM* Profile Simulation

Add profiles for each energy bin weighted by dose fraction
Final profile is consistent (minus the channeling tail)

| Dose Fractions by Boron Equivalent Energy | |
|---|---|
| Energy Bin (eV) | Dose Fraction (%) |
| 450 | 2.6 |
| 350 | 1.95 |
| 250 | 1.87 |
| 150 | 10.1 |
| 100 | 40.66 |
| 80 | 19.29 |
| 50 | 16.62 |
| 20 | 6.83 |

*Stopping and Range of Ions in Matter (SRIM), a numerical simulation by J. F. Ziegler and J. P. Biersack, http://www.srim.org/



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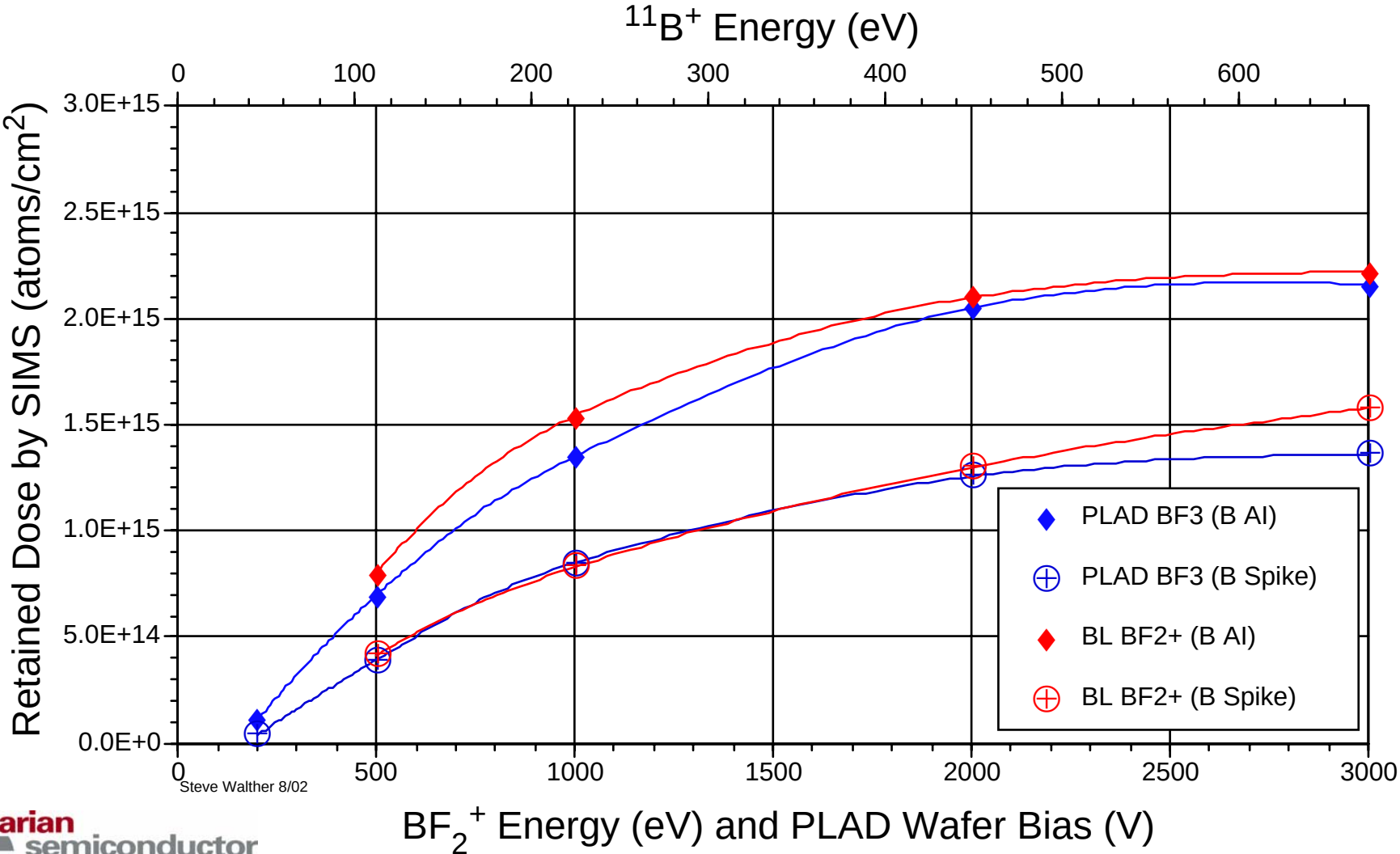
# SIMS Retained Dose for PLAD and Beamline
## As-implanted (3E15) and Spike Annealed

Equivalent dose control and retention over energy range



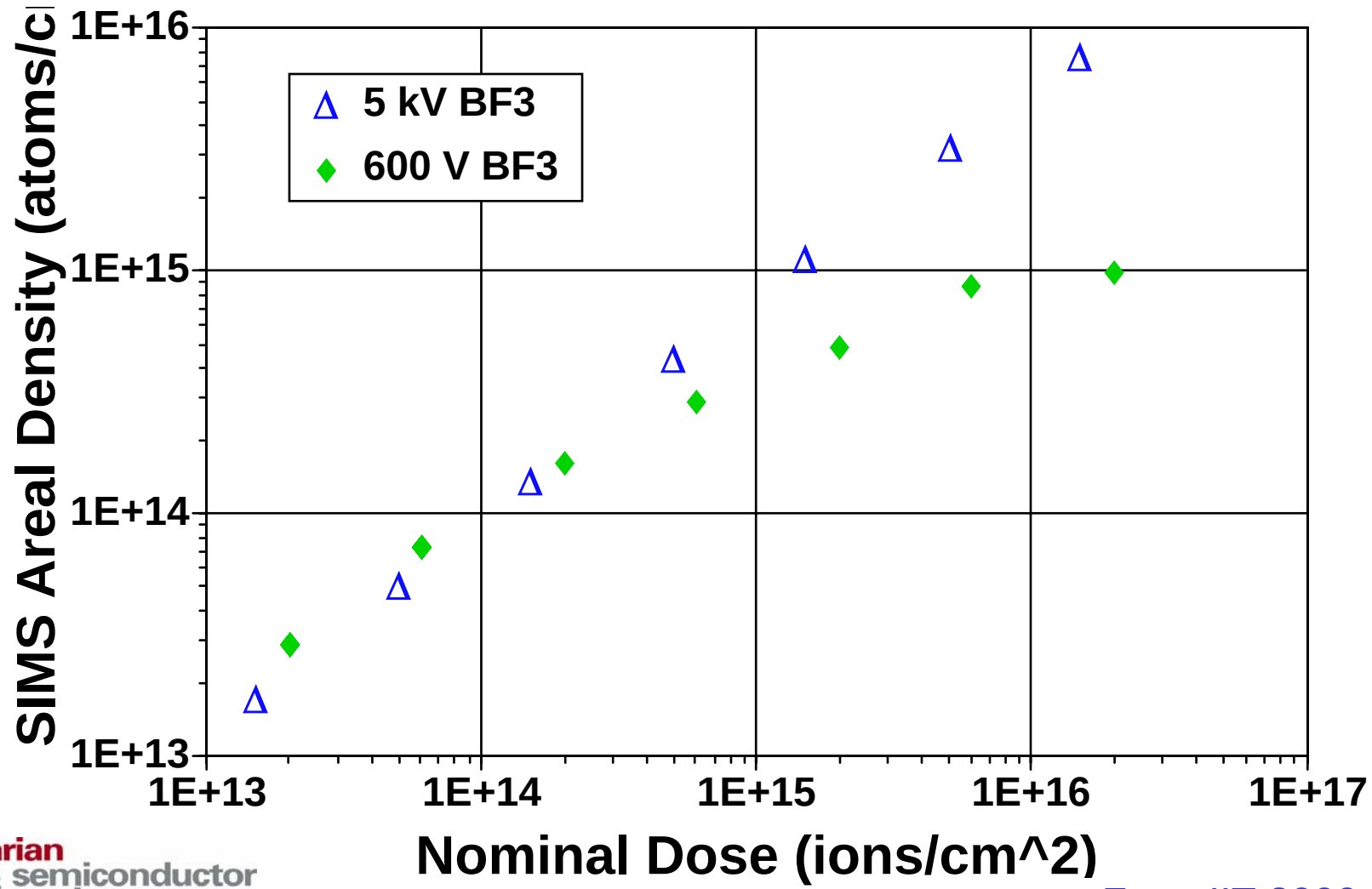

From IIT 2002

°C, 200 °C/s, Spike Anneal, AST 3000

# PLAD Dose Accuracy

## Nominal vs. SIMS Dose for PLAD $BF_3$ Implants

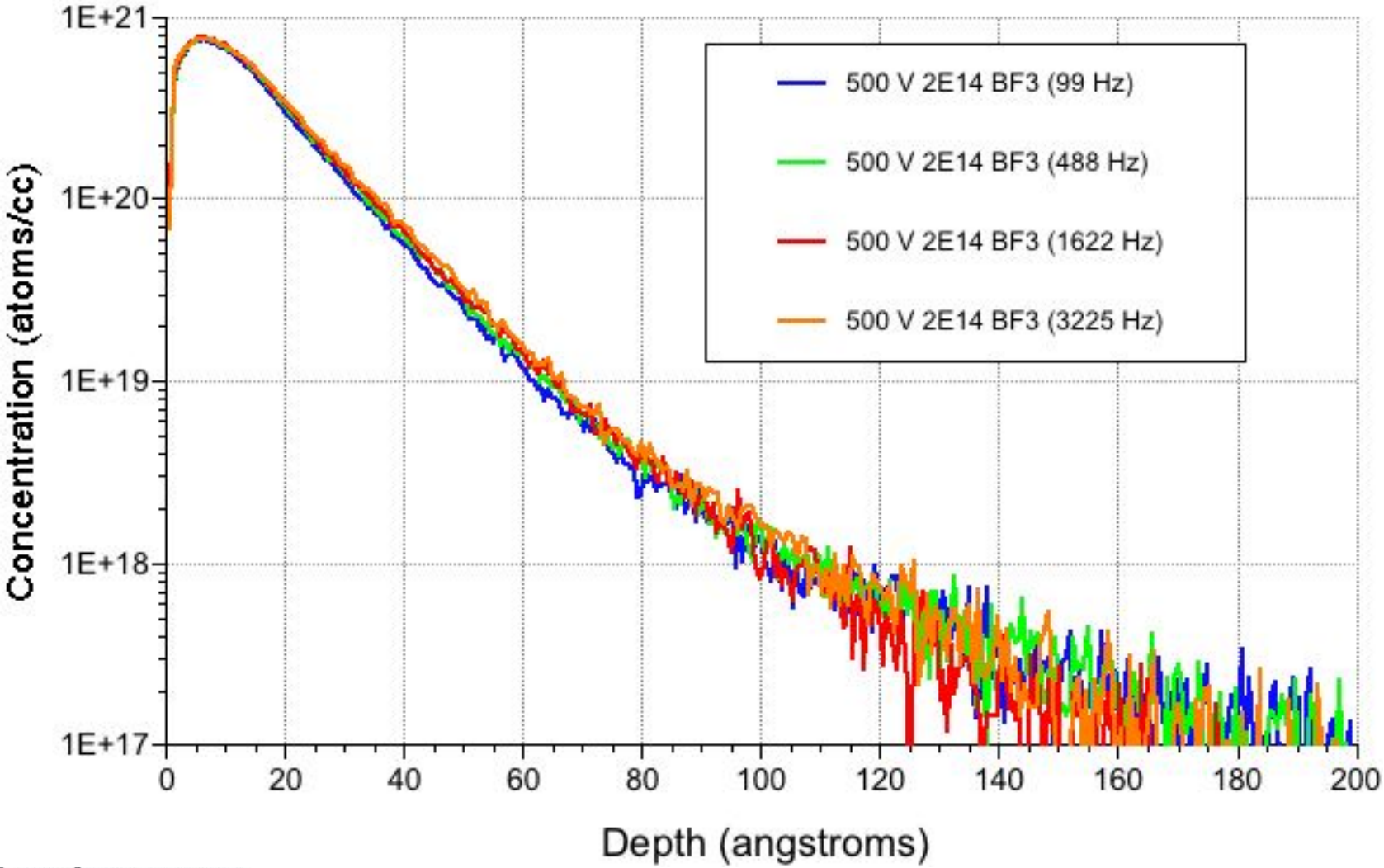
High surface dopant levels tend to saturation




From IIT 2000

# PLAD Profile Repeatability vs. Pulse Frequency

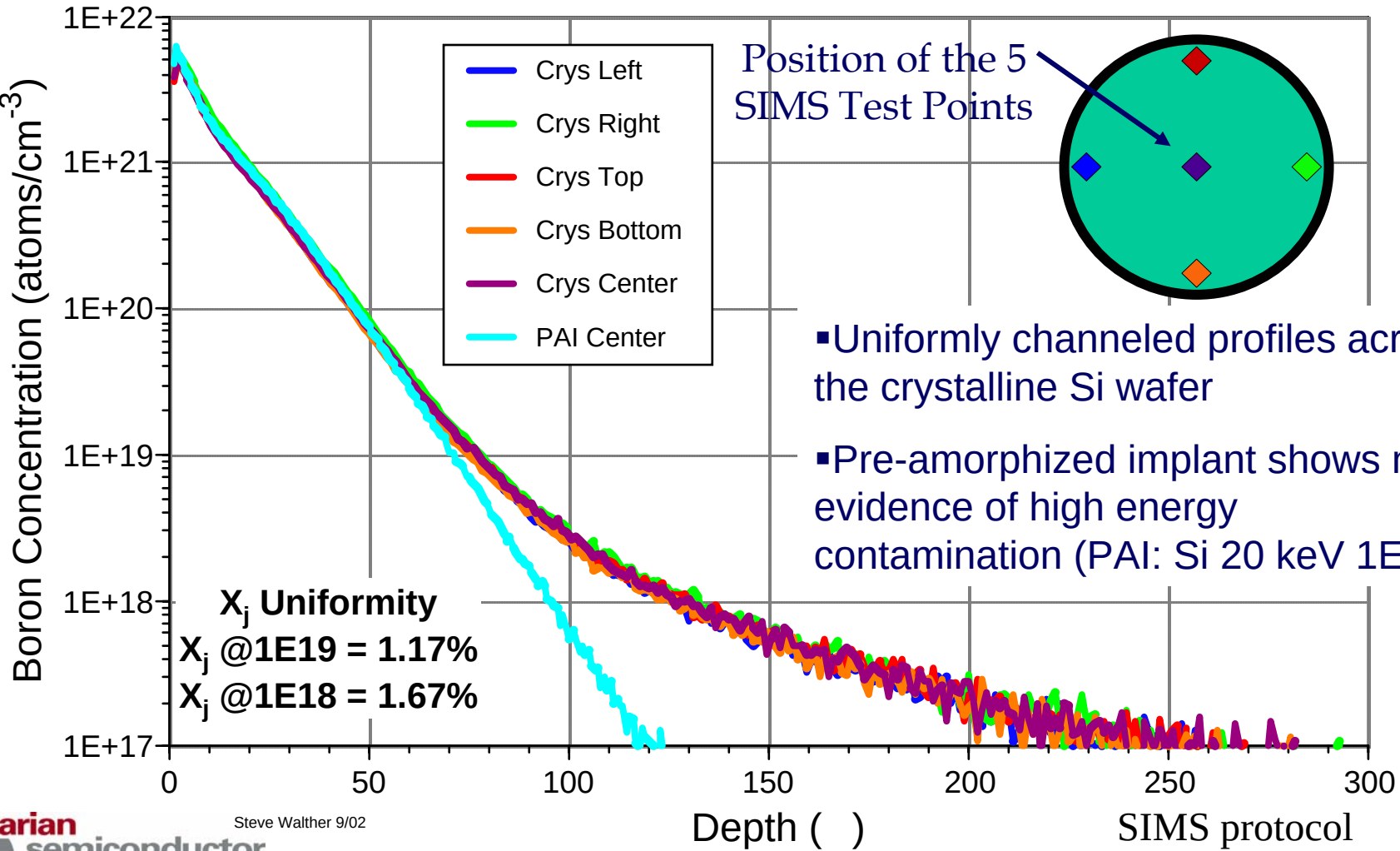
No surface effects from implantation between pulses



# PLAD Across Wafer $X_j$ Uniformity

## 500 V $BF_3$ Pre-amorphized and Crystalline As-implanted Boron Profiles

Repeatable profiles across the wafer, no edge effects




- Uniformly channeled profiles across the crystalline Si wafer
- Pre-amorphized implant shows no evidence of high energy contamination (PAI: Si 20 keV 1E15)

SIMS protocol
1 keV @ 45˚ $O_2$ leak

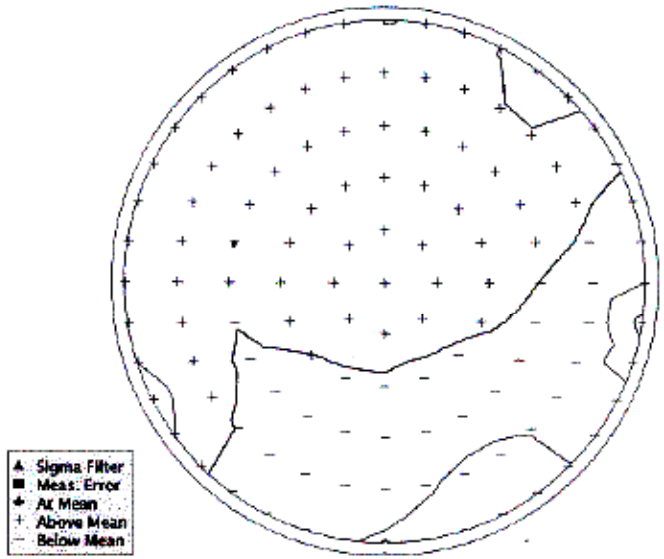
# PLAD 300 mm $BF_3$ 300 V 2.5E15 Across Wafer Dose Uniformity

**P = 35 mTorr**
**Spacing = 3.5 cm**
**Flow = 10 sccm**
**Anneal: 1000º deg**
**10 sec.**

**Uniformity = 1.9%**
**Avg. $R_s$ = 1137 Ω/sq**

KLA-Tencor OmniMap™ RS-100

October 10, 2002 18:03:02
CONTOUR (10/02)



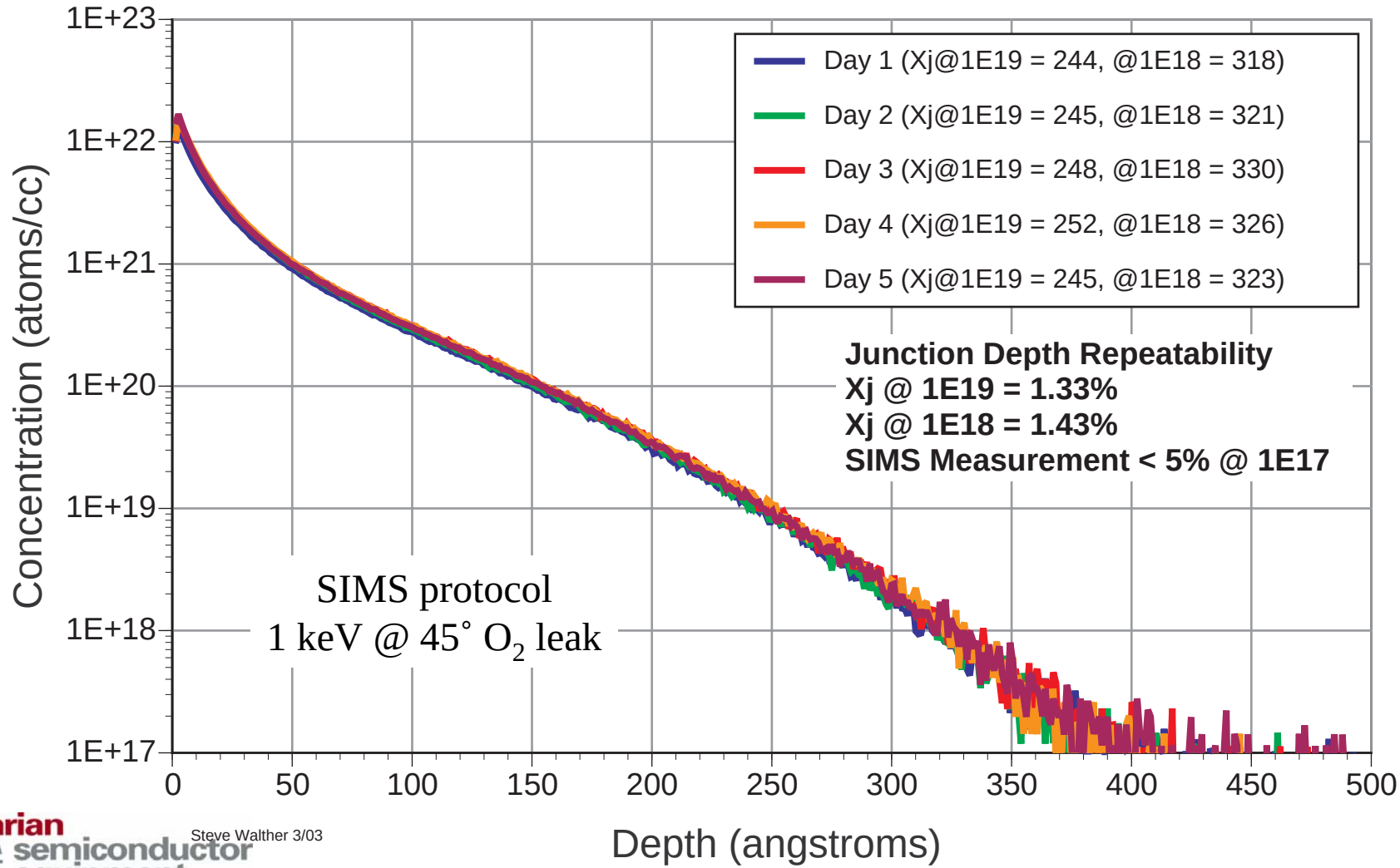

| | | | |
|---|---|---|---|
| Operator | SS "C" I27585A | Shift | INTEL/#3195 |
| Process | AST3002/3cl00010.102 | Equipment | PLAD #003 |
| Wafer ID | 1142-050NR | Process Date | October 10, 2002 |
| Lot ID | BF3 2.5E15 0.3kV | Process Time | 17:52:26 |
| Mean | 1.1374e+003 | Wafer Diam. | 300.00 mm / 11.81 in |
| Std Dev | 2.1567e+001 / 1.896% | Test Diam. | 285.00 mm / 11.22 in |
| Minimum / Maximum | 1.04e+003/1.19e+003 | Test Pattern | Contour Map, 121-Site |
| Range | 1.5221e+002 | Probe | 8.0 mil Tip - Type C |
| # Good / Sites | 121 / 121 | | |
| Sample Type | Auto Range | TCR Value | 0.0000 |
| Correct to Temp | 23.0°C | Meas Temp(BF/AF/AVG) | 24.92 / 25.78 / 25.35 °C |
| Amperage | 2.9630e+001 µA | Voltage | 7.5010 mV |
| Sigma Filter[U/L] | 6.0 / 6.0 | Target Mean | 0.0000e+000 |
| Correlation | | Warning Limit(U/L) | 0.0000e+000/0.0000e+000 |
| Units | Ohms/Sq | Control Limit(U/L) | 0.0000e+000/0.0000e+000 |
| | | Contour Interval | 1.0000e+000% |

From PBII 2003

# PLAD 5 Day $X_j$ Repeatability Test

## 3 kV 4E15 $BF_3$ on Pre-amorphized Wafers

## Repeatable profiles from day to day operation



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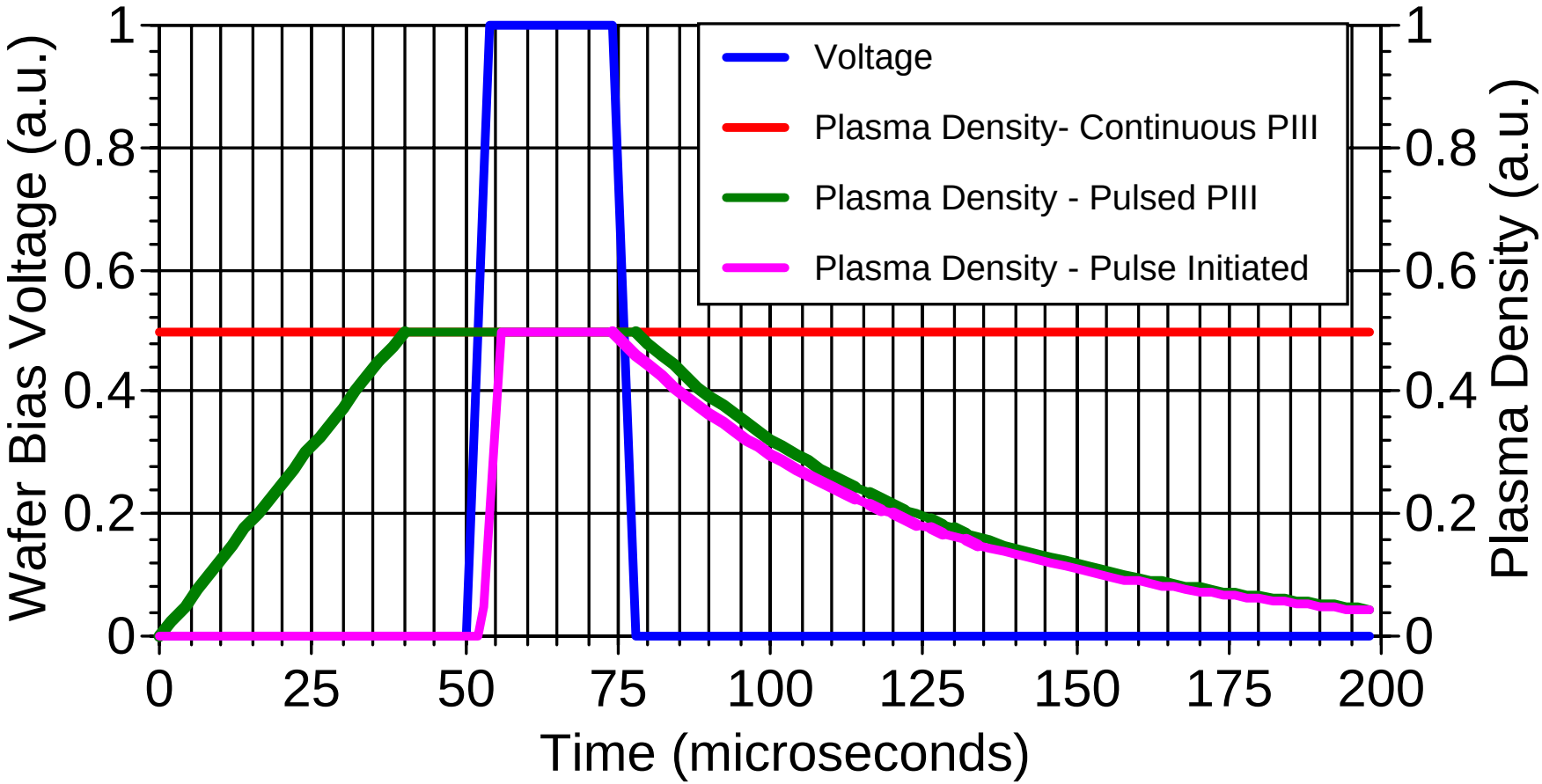
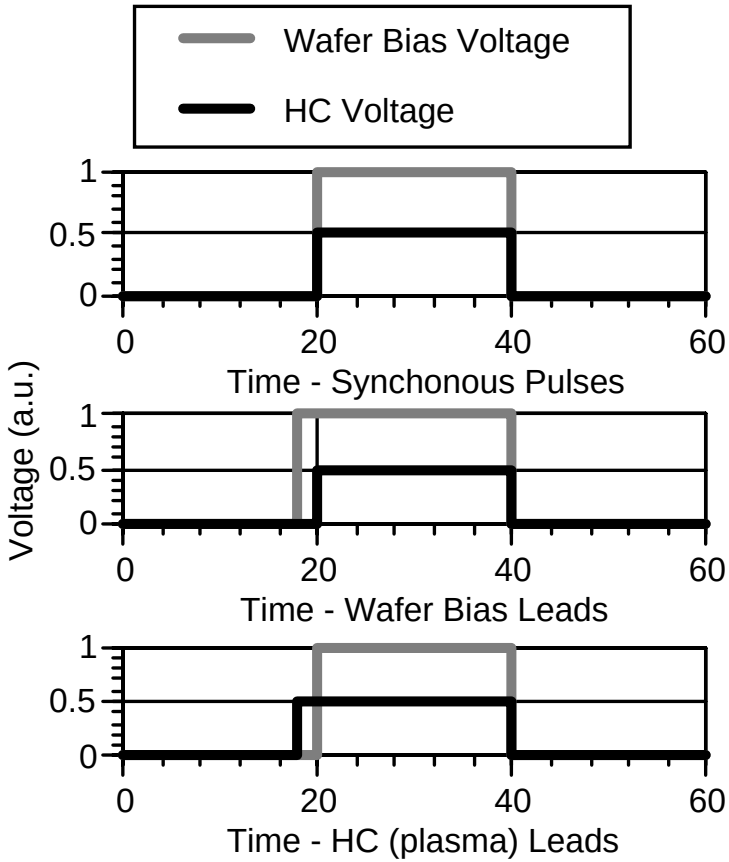
# Plasma Implant Timing Options

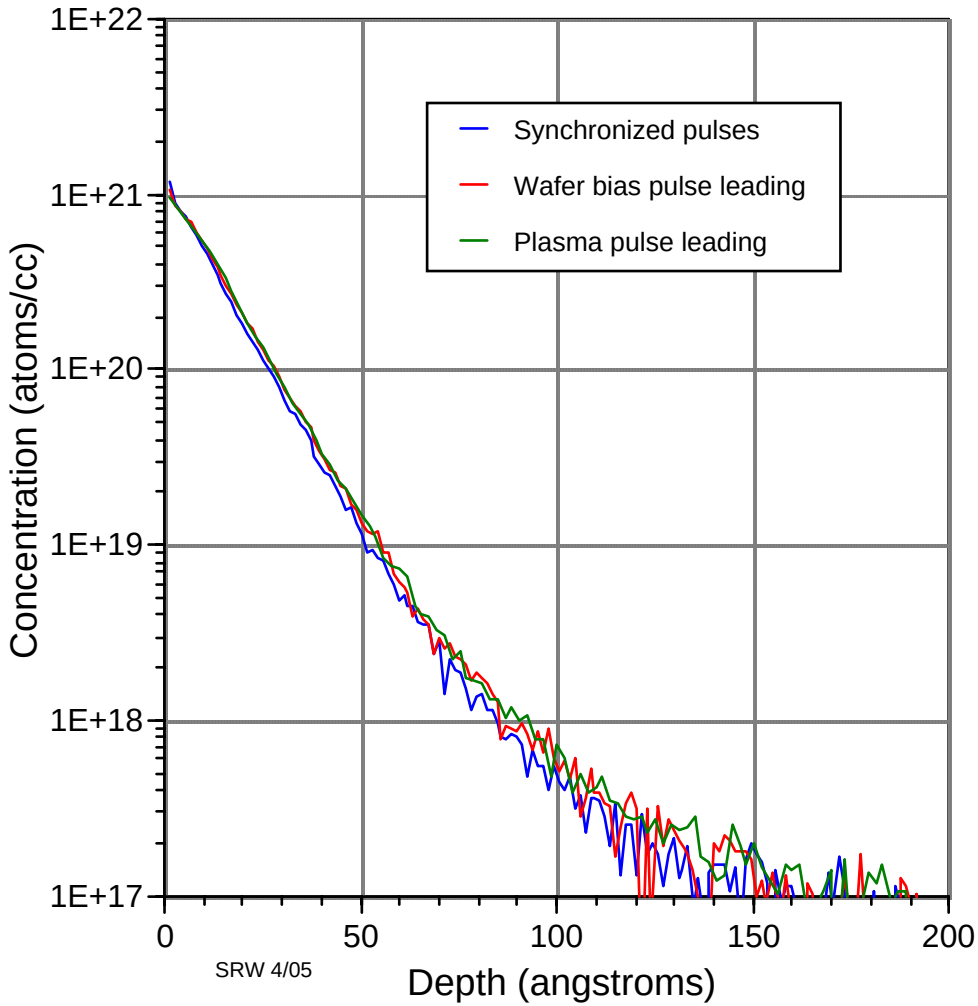
## Plasma may be continuous, short or long pulse



# Pulse Timing Plasma Sheath Effects

Depth profile insensitive to pulse timing
No significant matrix sheath even with plasma pulse leading




SRW 4/05

varian semiconductor equipment

SRW 6/05

# PLAD for Advanced USJ Summary

- VIISta HC & plasma implant USJ profiles match
  - Similar dose control systems
  - Consistent with plasma implant preponderance of 500 eV $BF_2^+$ measured using mass/energy diagnostic apparatus
- USJ retained dose behaves similarly to beamline implant (as a function of primary energy)
- USJ profile uniformity & repeatability demonstrated
- USJ profiles not sensitive to relative timing of wafer bias & plasma generation pulses

# Acknowledgements


- Carl Ellis
- Guy Oteri
- Svetlana Radovanov
- Ziwei Fang
- John Koo