SiC MOSFET Corner and Statistical SPICE Model Generation

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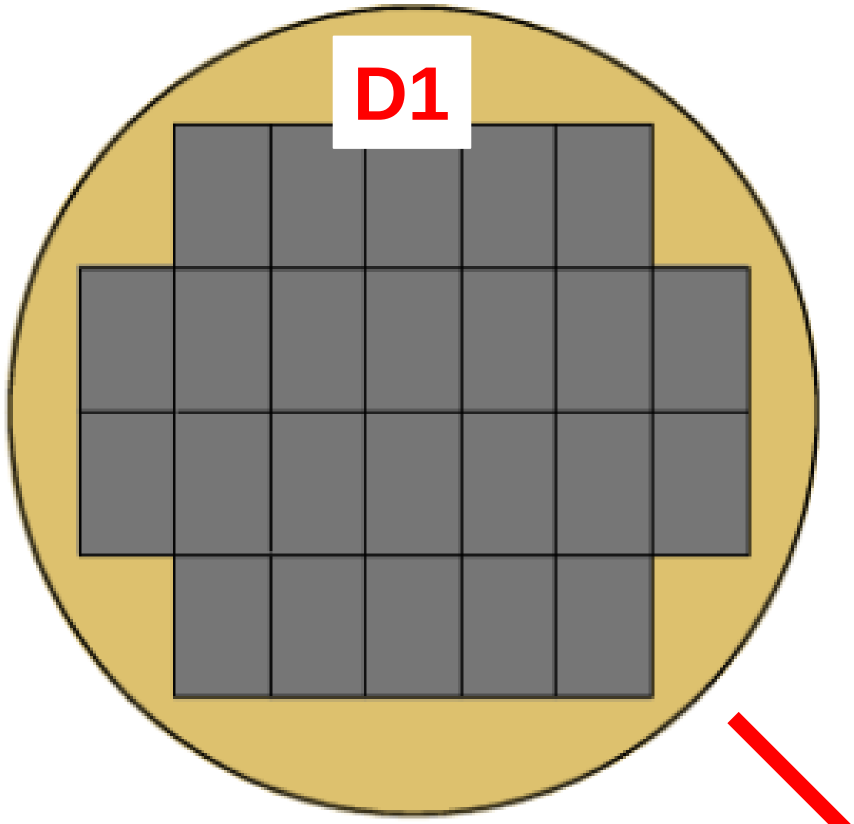
Outline

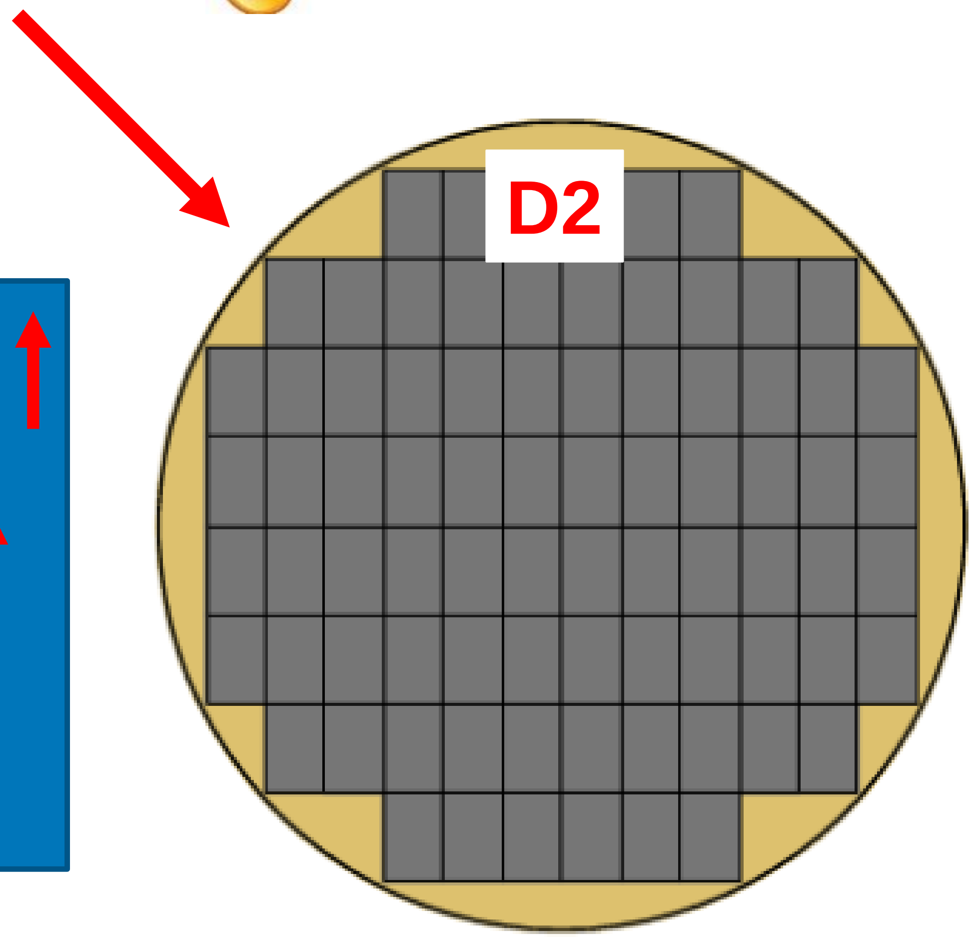
- Motivation for Corner and Statistical SPICE models for power devices
- Discussion on Physically Based SPICE Models
- Backward Propagation of Variance (BPV) Technique Applied to SiC MOSFETs
- Experimental Results and Verification
- Conclusion

Why do we care about corner and statistical SPICE models in power devices?

- Datasheets historically contain wide uncorrelated parameter ranges that are not always representative of the true manufacturing process variation.

RDSon Variation	RDSon MAX	RDSon Typical	Die Area	D1 > D2
25%	1	0.8	D1	
11%	1	0.9	D2	





GDPW ↑

Yield ↑

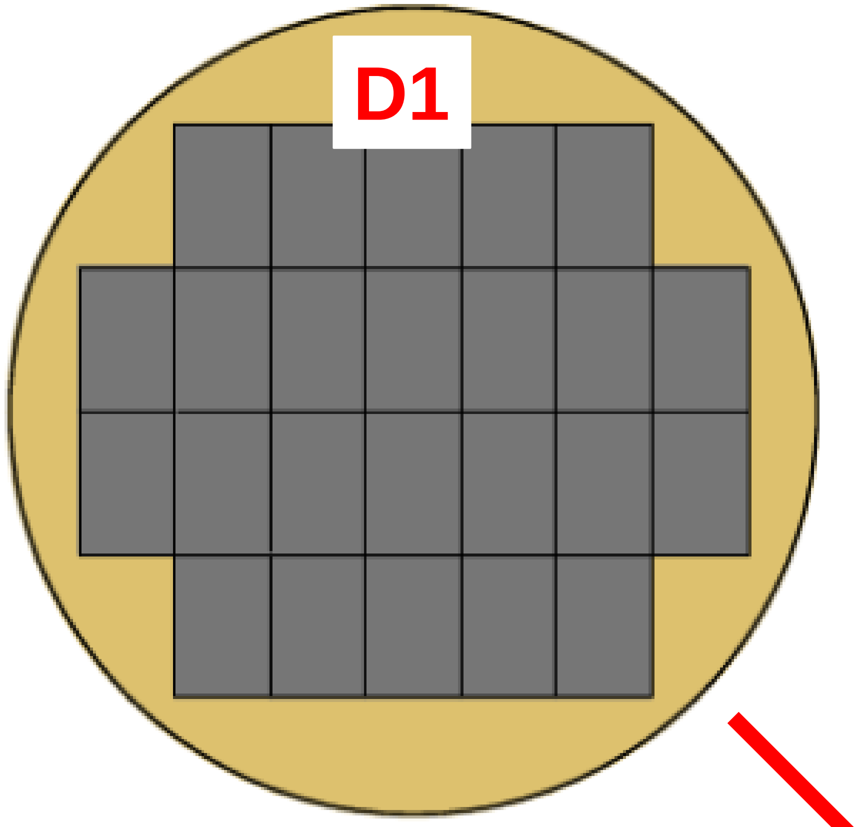
Q_G ↓

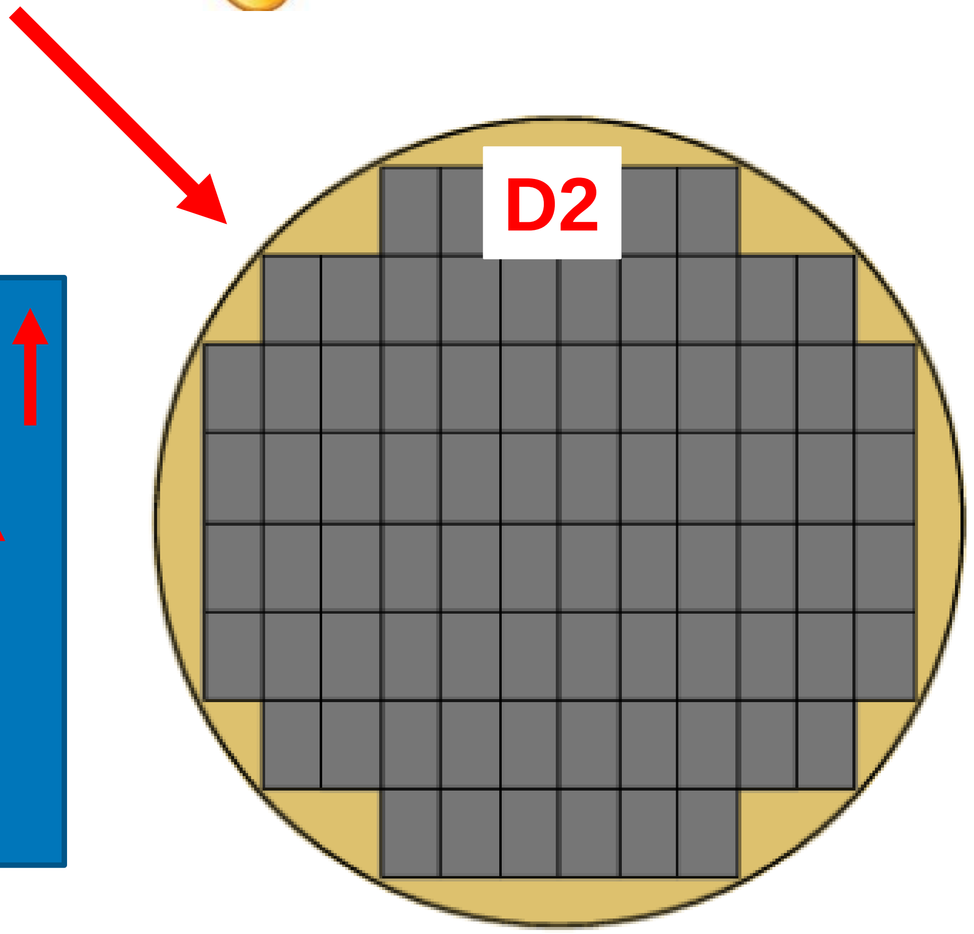
Why do we care about corner and statistical SPICE models in power devices?

- Datasheets historically contain wide uncorrelated parameter ranges that are not always representative of the true manufacturing process variation.

RDSon Variation	RDSon MAX	RDSon Typical	Die Area	
25%	1	0.8	D1	**D1 > D2**
11%	1	0.9	D2	

- Design for optimized performance and robustness to semiconductor process variation through simulation is critical to ensure high yield and high performance of a chip throughout the manufacturing lifetime. This is well understood in the IC CAD industry.



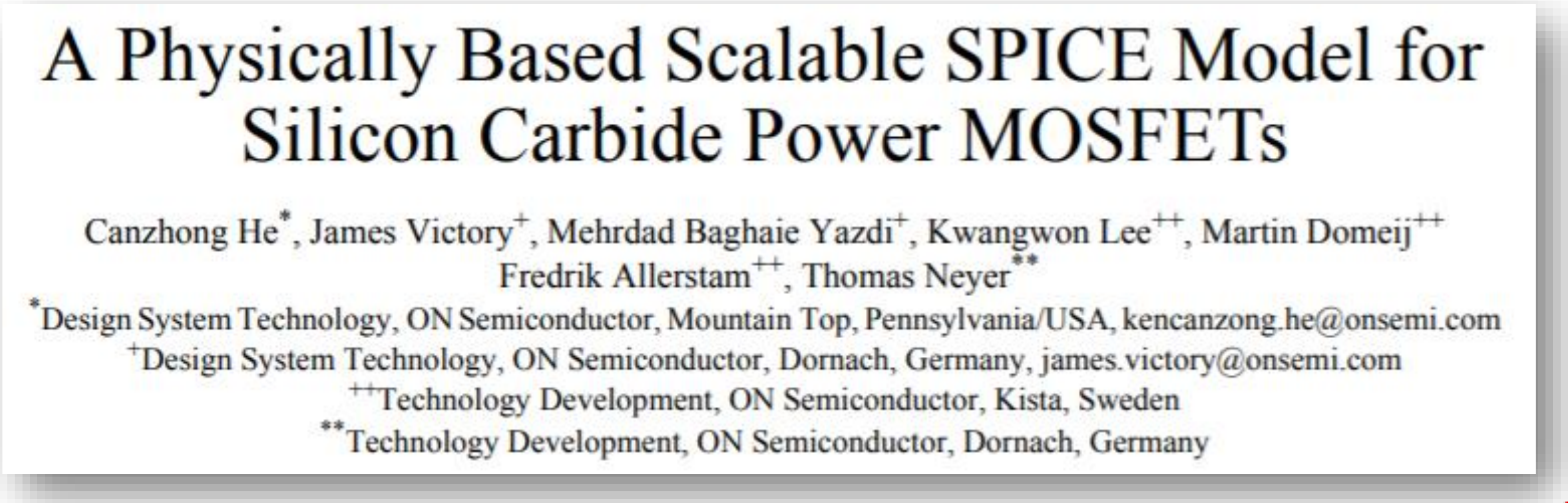


GDPW ↑
Yield ↑
Q_G ↓

Why not in power devices?

Discussion on Physically Based SPICE Models

- SPICE models should be physically based and scalable with process and layout parameters.
  - Enables accurate, consistent, and correlated process variation modeling and simulation
  - IC industry standard practice
- Recent advances in power device modeling has opened the door to apply physically based, statistical techniques for process variation simulation.



A Physically Based Scalable SPICE Model for Silicon Carbide Power MOSFETs

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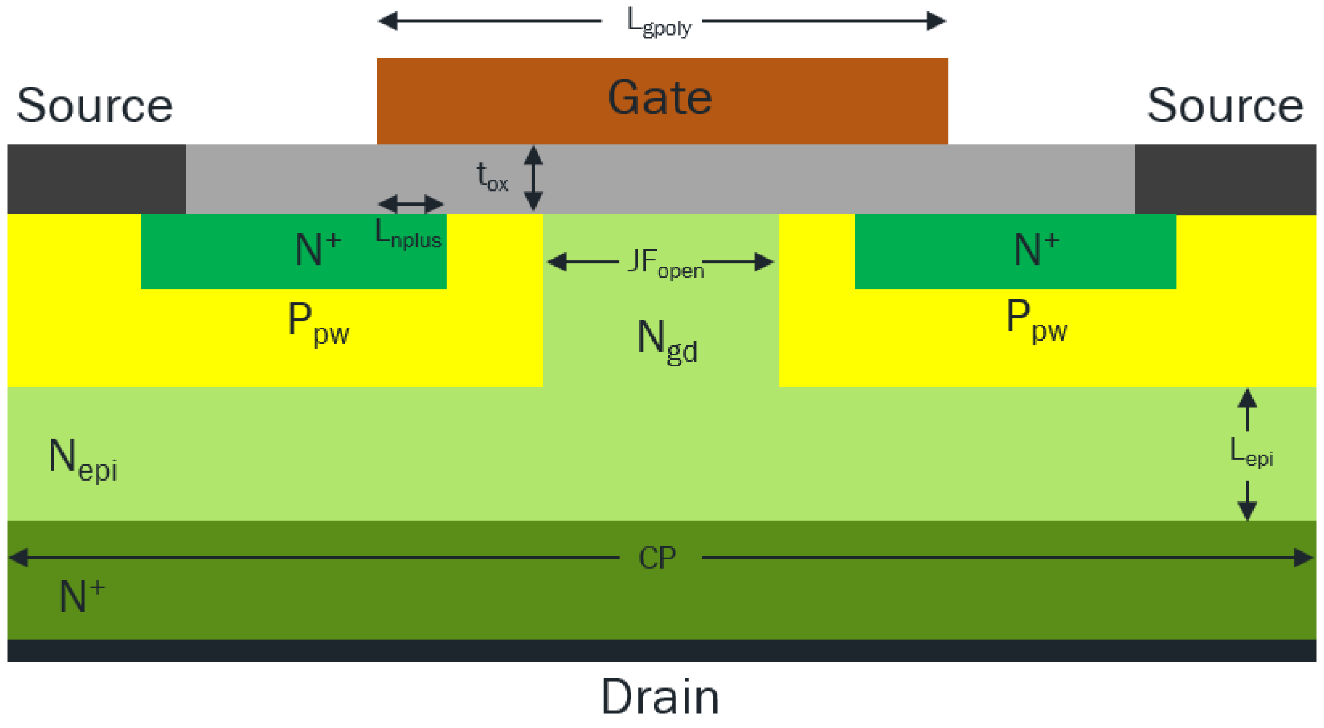
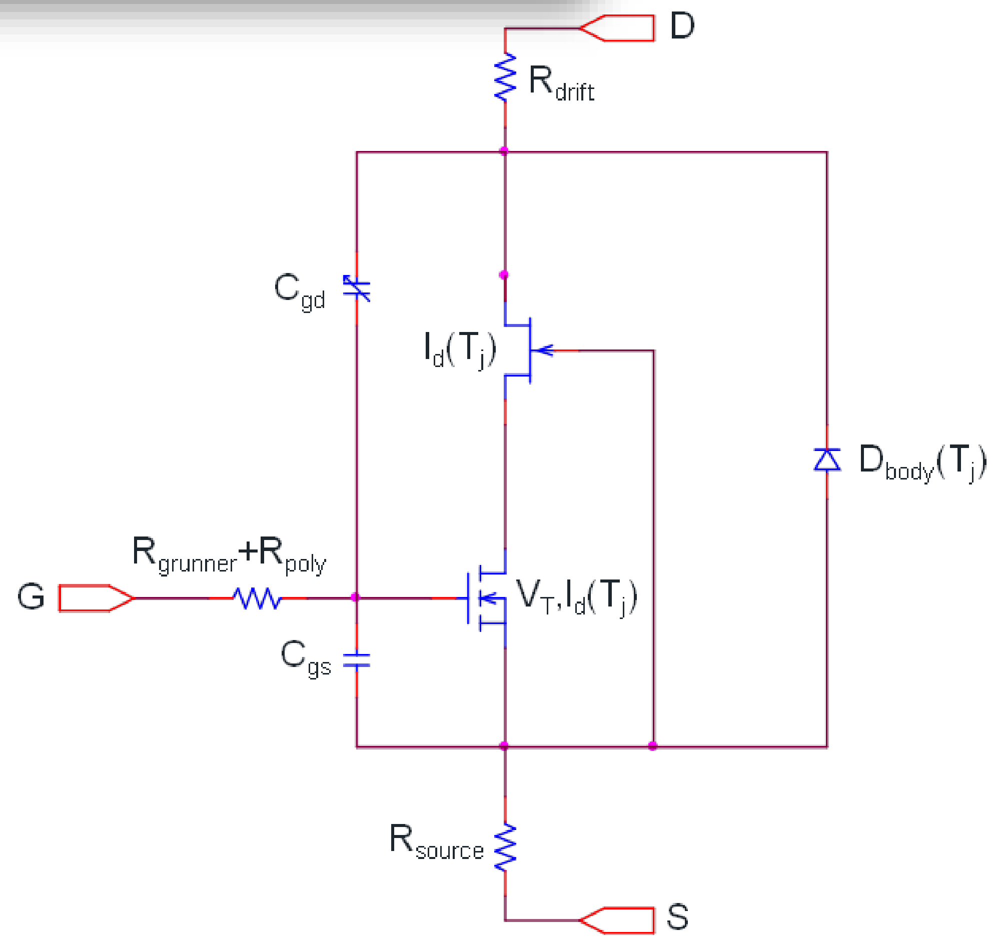
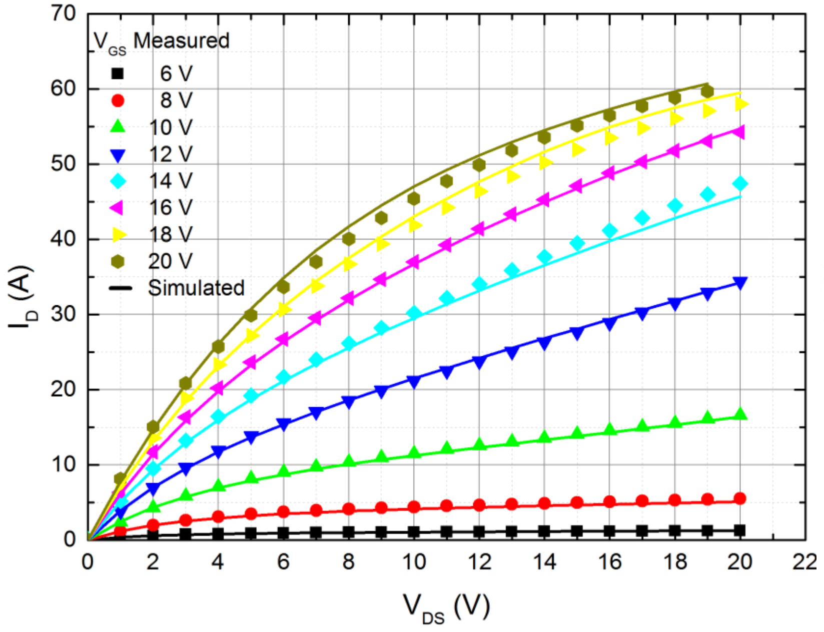




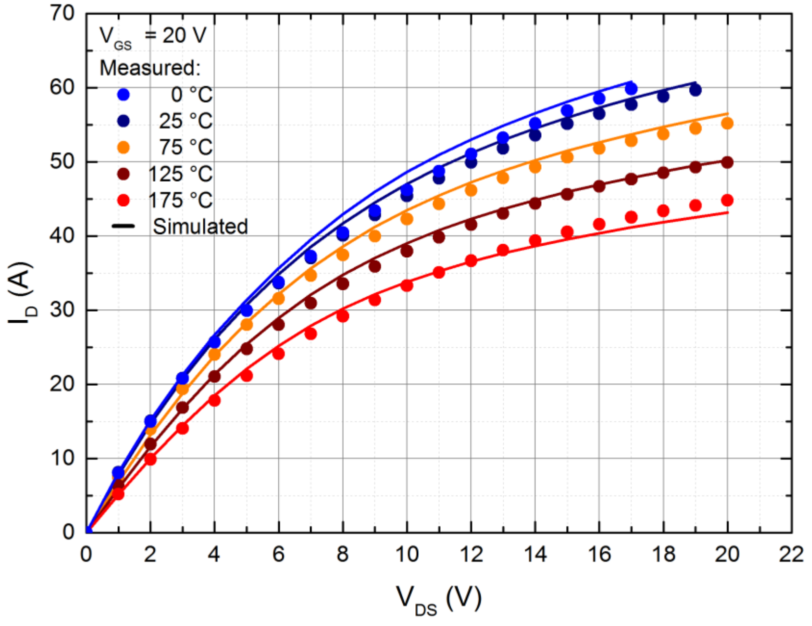
Physical Structure → Physical, Scalable Model

Typical SiC MOSFET SPICE Model Results

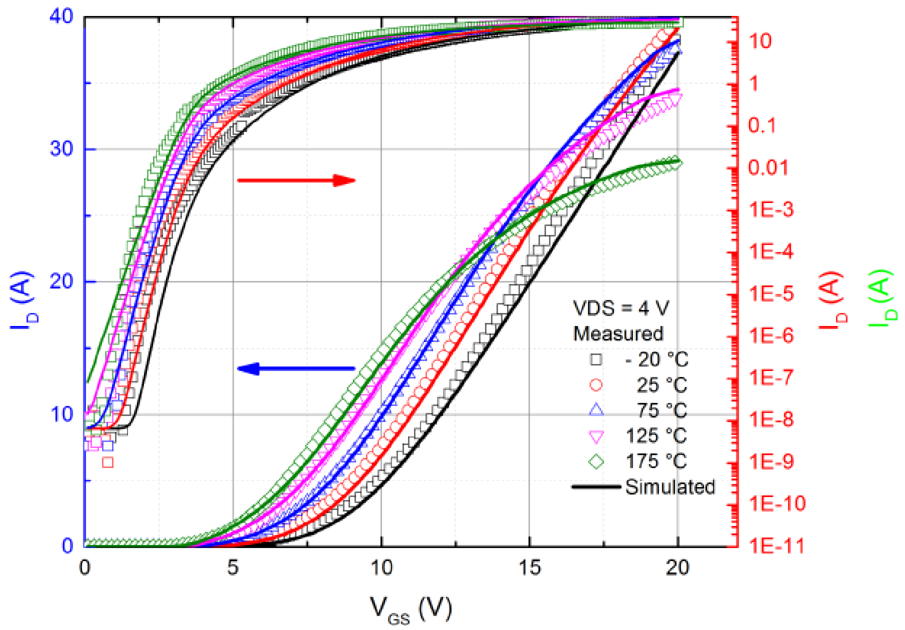
I_DV_D



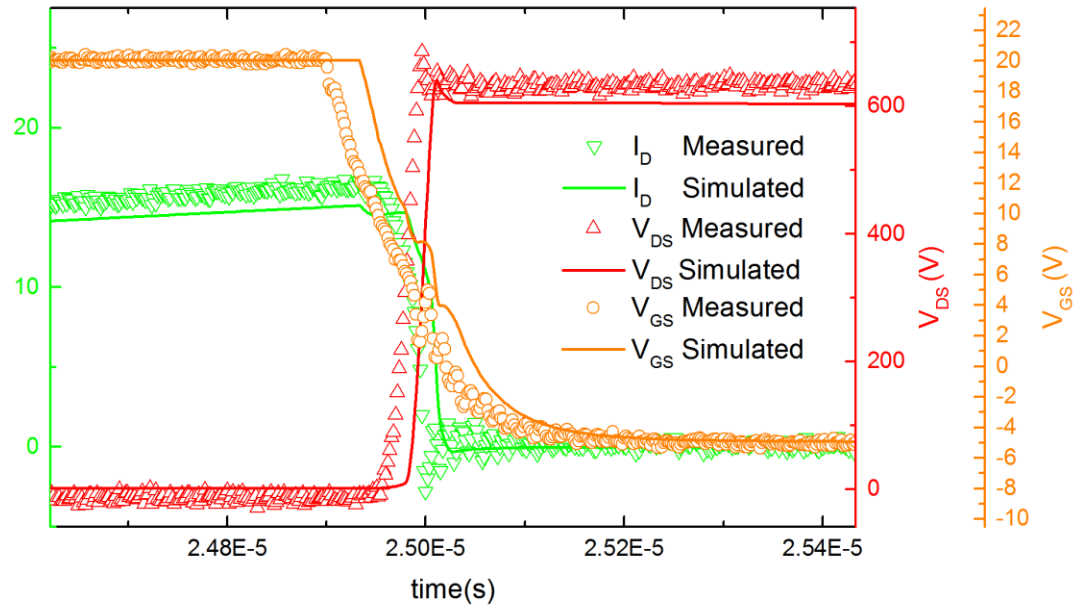
I_DV_D(T)



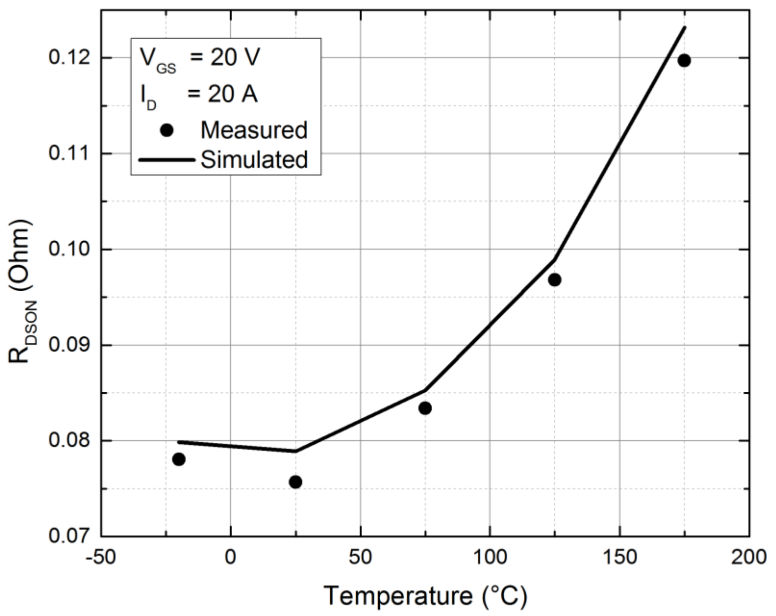
I_DV_G(T)



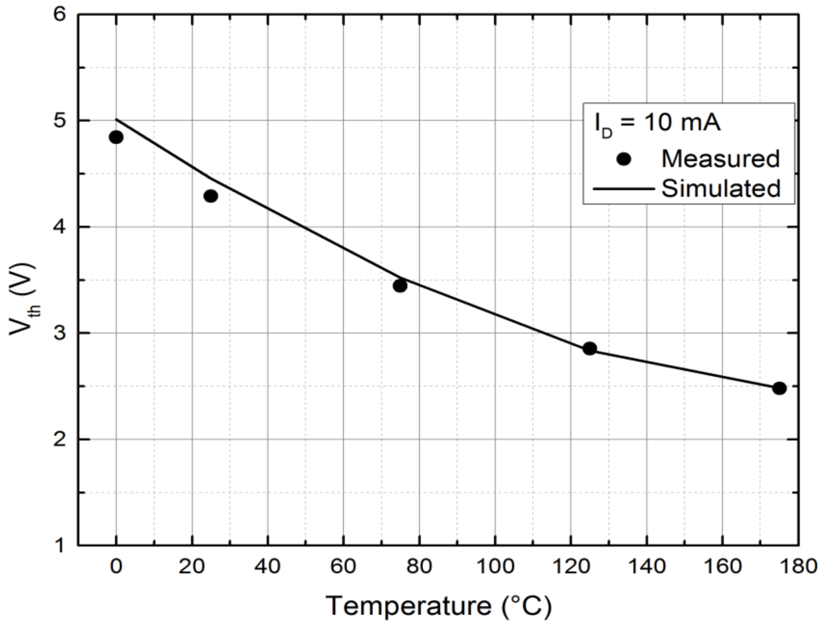
Double Pulse OFF



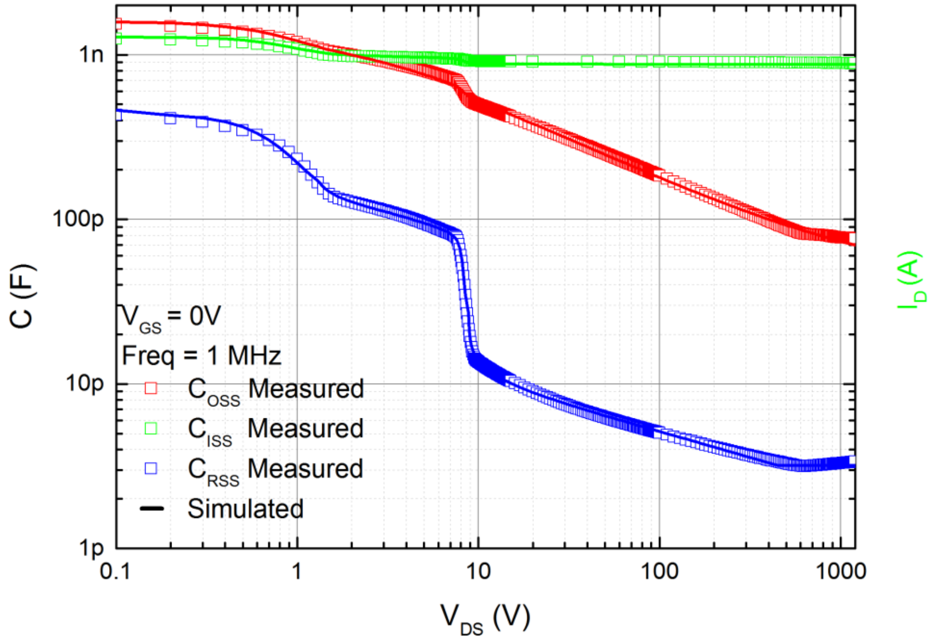
R_{DSon}(T)



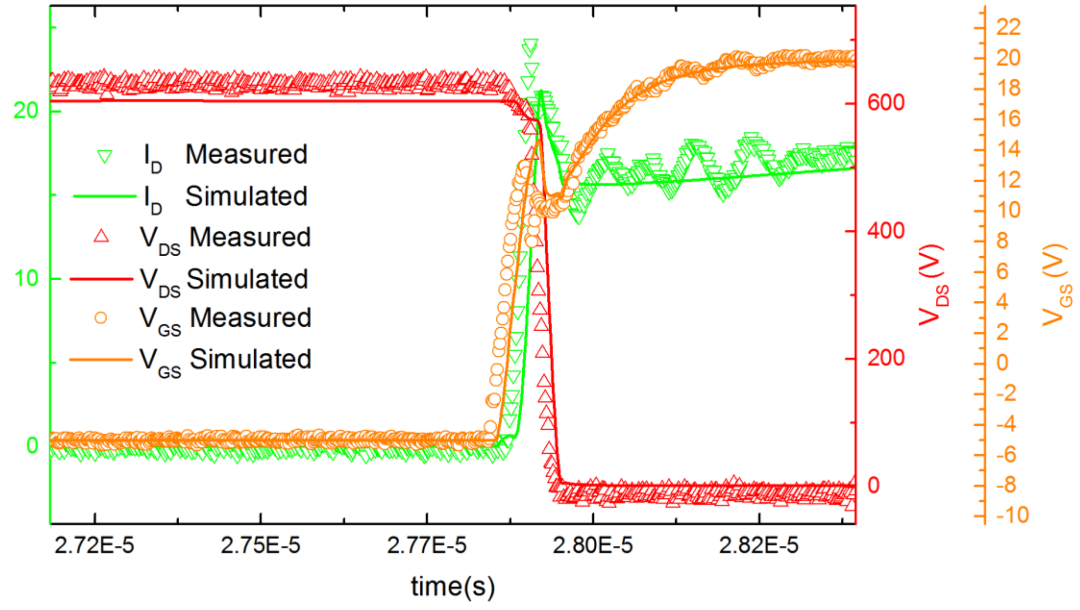
V_{th}(T)



CV



Double Pulse ON



BPV (Backward Propagation of Variance) Technique Applied to SiC MOSFETs

- Variances (σ^2) of electrical performances E are based on manufacturing data.
- Sensitivities $\frac{\partial E_i}{\partial P_j}$ are computed through SPICE model simulation.
- Goal is to accurately simulate the variation of electrical performances E.
- BPV equations solve for the variances of the SPICE model process parameters P.

"Guarantees"

SPICE E = Measured E

SPICE Process Parameters P

Parameter	Description
Tox	Gate Oxide Thickness
Lnplus	Gate Poly Overlap of N+ Source
JFopen	JFET Width
Lgpoly	Gate Poly Length
Nchpk	Peak Channel Doping
Ppw	Pwell Doping
Ngd	Epi Doping under Gate Poly, JFET
Lepi	Epi Thickness, distance btw deep Pwell
Nepi	Epi Doping
Mj	Body Diode Grading Coeff.
µch	Channel Mobility
µdr	Drift Mobility

Electrical Performances E

E	Description
Vth	Vth @ 5mA
RDSonhi	RDSon @ VG=20, ID=20
RDSonlo	RDSon @ VG=15, ID=5
BVdss	BV @ 100uA
CissHV	Ciss @ VD=20V
CrssLV	Crss @ VD=1mV
CrssMV	Crss @ VD=5V
CrssHV	Crss @ VD=20V
CossLV	Coss @ VD=1mV
CossHV	Coss@ VD=20V
Qg	Qg @ VDS=800, VG=20, ID=20

Base BPV Solution

$$\sigma^2_{\delta E_i} = \sum_j \left(\frac{\partial E_i}{\partial P_j}\right) \cdot \sigma^2_{\delta P_j}$$

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"Guarantees"

SPICE E = Measured E

SPICE Process Parameters P   Electrical Performances E

There are NO parameters R_{DSon} or C_{rss} for example

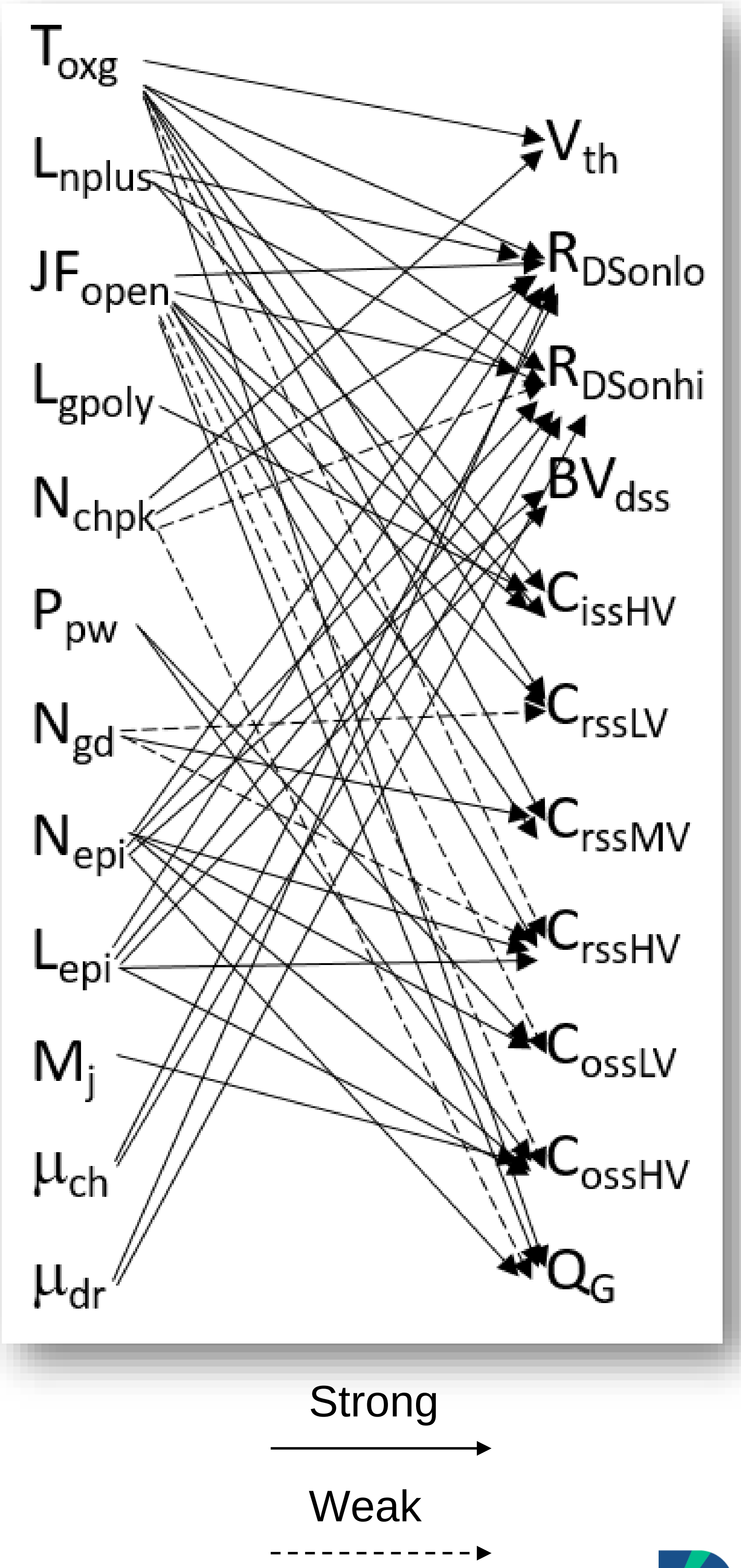
There are uncorrelated process parameters that induce correlated shifts in R_{DSon} or C_{rss}.

Base BPV Solution

$$\sigma^2_{\delta E_i} = \sum_j \left(\frac{\partial E_i}{\partial P_j}\right) \cdot \sigma^2_{\delta P_j}$$

BPV Technique Discussion

- E and P must be chosen such that perturbations in P are observable in of E.
  - Need a physical SPICE model with well defined P
  - Need consistent and sufficient E
  - In general, system should be X “equations” and X “unknowns”. X=11 in our SiC MOSFET case.
- The technique fails when
  - There are inconsistencies in specification of the E statistics. Computed P variances can become negative.
  - The underlying SPICE models are inaccurate and unphysical leading to an ill conditioned sensitivity matrix.
- Not a “garbage in garbage out” process
  - Issues with the SPICE models and manufacturing data can be exposed through the BPV technique.



Full SiC MOSFET BPV Solution

$$
\begin{bmatrix}
\sigma^2_{\delta V_{th}} - \left(\frac{\partial V_{th}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta R_{DSonlo}} - \left(\frac{\partial R_{DSonlo}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta R_{DSonhi}} - \left(\frac{\partial R_{DSonhi}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta BV_{dss}} - \left(\frac{\partial BV_{dss}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta C_{issHV}} - \left(\frac{\partial C_{issHV}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta C_{rssLV}} - \left(\frac{\partial C_{rssLV}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta C_{rssMV}} - \left(\frac{\partial C_{rssMV}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta C_{rssHV}} - \left(\frac{\partial C_{rssHV}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta C_{ossLV}} - \left(\frac{\partial C_{ossLV}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta C_{ossHV}} - \left(\frac{\partial C_{ossHV}}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}} \\
\sigma^2_{\delta Q_G} - \left(\frac{\partial Q_G}{\partial T_{ox}}\right)^2 \sigma^2_{\delta T_{ox}}
\end{bmatrix}
=
\begin{bmatrix}
\left(\frac{\partial V_{th}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial V_{th}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial V_{th}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial V_{th}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial V_{th}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial V_{th}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial V_{th}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial V_{th}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial V_{th}}{\partial M_j}\right)^2 & \left(\frac{\partial V_{th}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial V_{th}}{\partial \mu_{dr}}\right)^2 \\
\left(\frac{\partial R_{DSonlo}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial M_j}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial \mu_{dr}}\right)^2 \\
\left(\frac{\partial R_{DSonhi}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial M_j}\right)^2 & \left(\frac{\partial R_{DSonhi}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial R_{DSonlo}}{\partial \mu_{dr}}\right) \\
\left(\frac{\partial BV_{dss}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial M_j}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial BV_{dss}}{\partial \mu_{dr}}\right) \\
\left(\frac{\partial C_{issHV}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial M_j}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial C_{issHV}}{\partial \mu_{dr}}\right) \\
\left(\frac{\partial C_{rssLV}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial M_j}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial C_{rssLV}}{\partial \mu_{dr}}\right) \\
\left(\frac{\partial C_{rssMV}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial M_j}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial C_{rssMV}}{\partial \mu_{dr}}\right) \\
\left(\frac{\partial C_{rssHV}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial M_j}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial C_{rssHV}}{\partial \mu_{dr}}\right) \\
\left(\frac{\partial C_{ossLV}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial M_j}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial C_{ossLV}}{\partial \mu_{dr}}\right) \\
\left(\frac{\partial C_{ossHV}}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial JF_{open}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial P_{pw}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial N_{gd}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial N_{epi}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial L_{epi}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial M_j}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial C_{ossHV}}{\partial \mu_{dr}}\right) \\
\left(\frac{\partial Q_G}{\partial L_{nplus}}\right)^2 & \left(\frac{\partial Q_G}{\partial JF_{open}}\right)^2 & \left(\frac{\partial Q_G}{\partial L_{gpoly}}\right)^2 & \left(\frac{\partial Q_G}{\partial N_{chpk}}\right)^2 & \left(\frac{\partial Q_G}{\partial P_{pw}}\right)^2 & \left(\frac{\partial R_G}{\partial N_{gd}}\right)^2 & \left(\frac{\partial Q_G}{\partial N_{epi}}\right)^2 & \left(\frac{\partial Q_G}{\partial L_{epi}}\right)^2 & \left(\frac{\partial Q_G}{\partial M_j}\right)^2 & \left(\frac{\partial Q_G}{\partial \mu_{ch}}\right)^2 & \left(\frac{\partial Q_G}{\partial \mu_{dr}}\right)
\end{bmatrix}
\begin{bmatrix}
\sigma^2_{\delta L_{nplus}} \\
\sigma^2_{\delta JF_{open}} \\
\sigma^2_{\delta L_{gpoly}} \\
\sigma^2_{\delta N_{chpk}} \\
\sigma^2_{\delta P_{pw}} \\
\sigma^2_{\delta N_{gd}} \\
\sigma^2_{\delta N_{epi}} \\
\sigma^2_{\delta L_{epi}} \\
\sigma^2_{\delta M_j} \\
\sigma^2_{\delta \mu_{ch}} \\
\sigma^2_{\delta \mu_{dr}}
\end{bmatrix}
$$

FPV T_{ox}: Forward propagated parameters, $\sigma^2_{\delta T_{ox}}$ known from manufacturing

SiC MOSFET Corner Model Solution

- Corner model solution has delta E as inputs and delta P as outputs.
- Same sensitivity matrix is used.
- E definition must be physically consistent based on known device correlations.
- Simple Worst and Best case could be defined based on R_{DSon} for example.
  - R_{DSon} and BV are positively correlated
- Corner definitions depends on what is important for designers.

Corner Model Solution

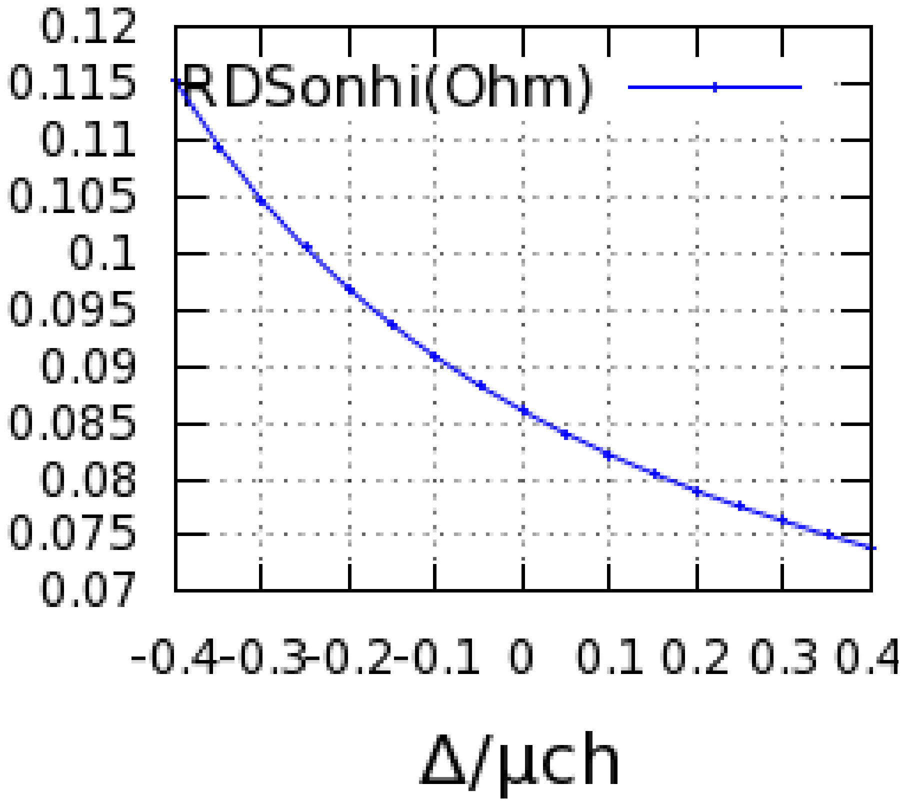
$$\delta E_i = \sum_j \left(\frac{\partial E_i}{\partial P_j}\right) \cdot \delta P_j$$

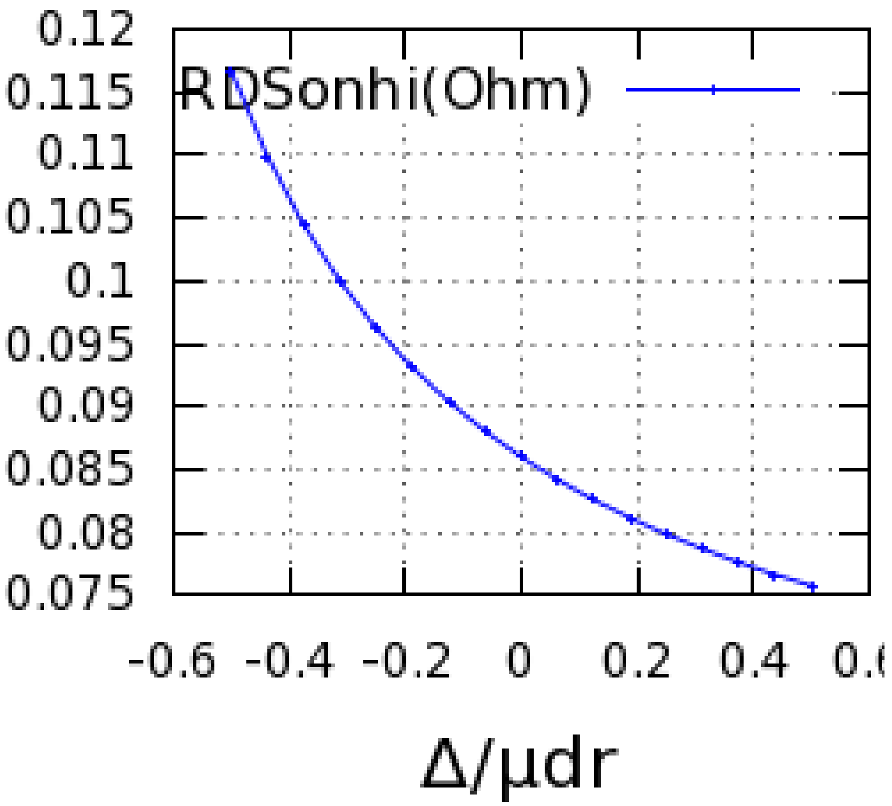
E	Corner 1	Corner 2
Vth	LOW	HIGH
RDSonhi	LOW	HIGH
RDSonlo	LOW	HIGH
BVdss	LOW	HIGH
CissHV	HIGH	LOW
CrssLV	HIGH	LOW
CrssMV	HIGH	LOW
CrssHV	HIGH	LOW
CossLV	HIGH	LOW
CossHV	HIGH	LOW
Qg	HIGH	LOW

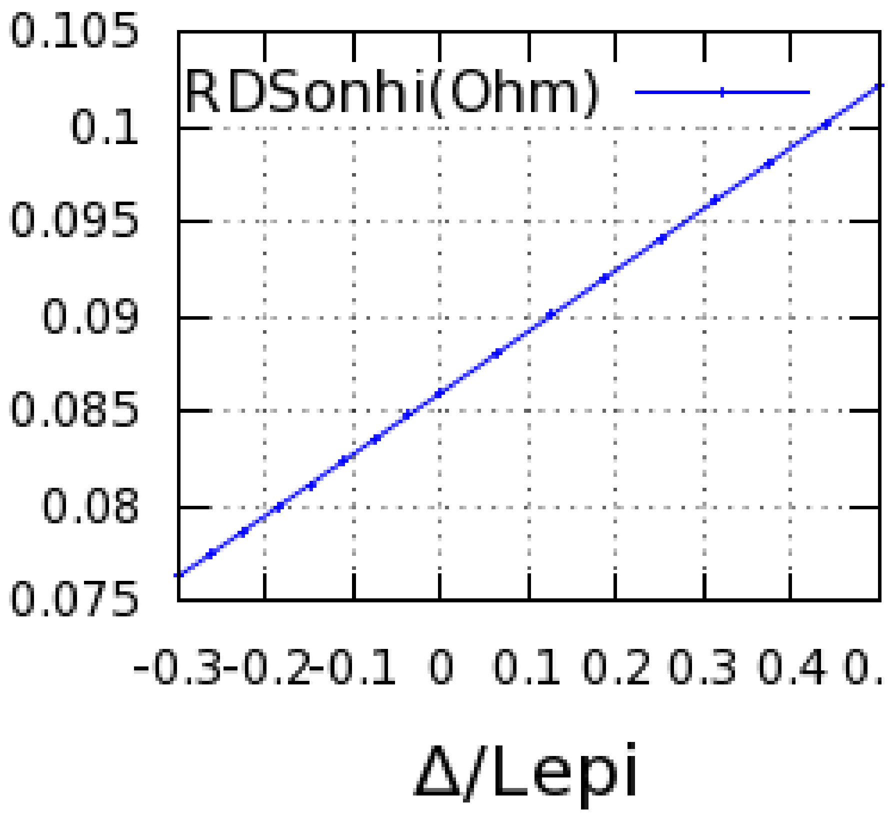
Sample R_{DSonhi} Sensitivity Plots

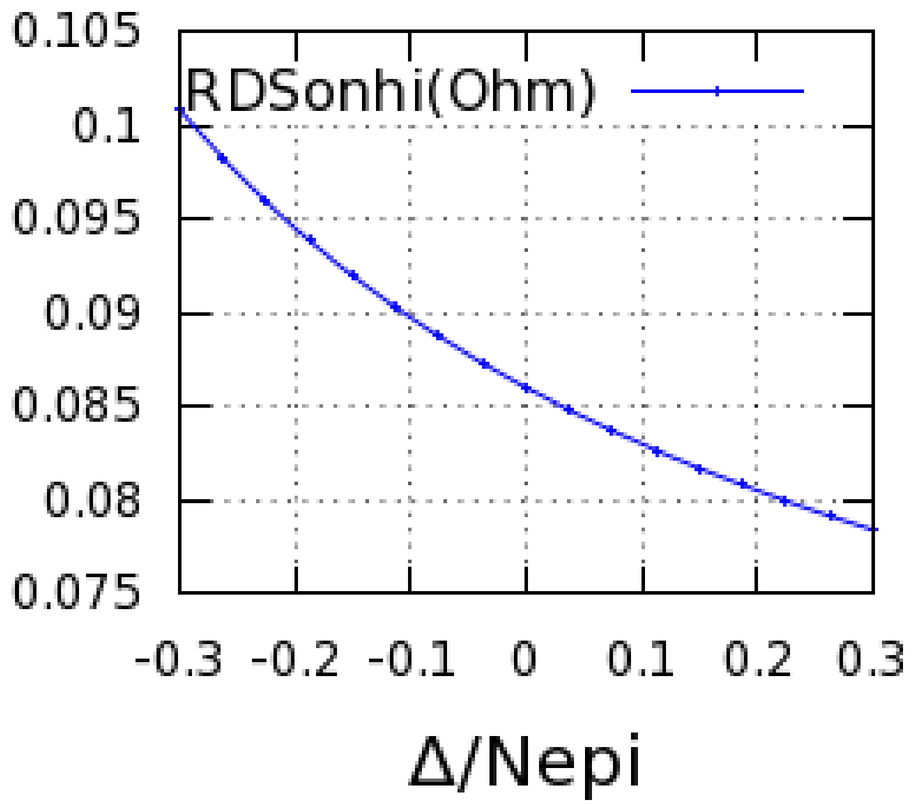
- Correct physical sensitivities are evident.
- Smooth, continuous behaviour facilitates BPV convergence.

Channel Mobility μ_{ch}	Drift Mobility μ_{dr}	Epi Thickness L_{epi}	Epi Doping N_{epi}









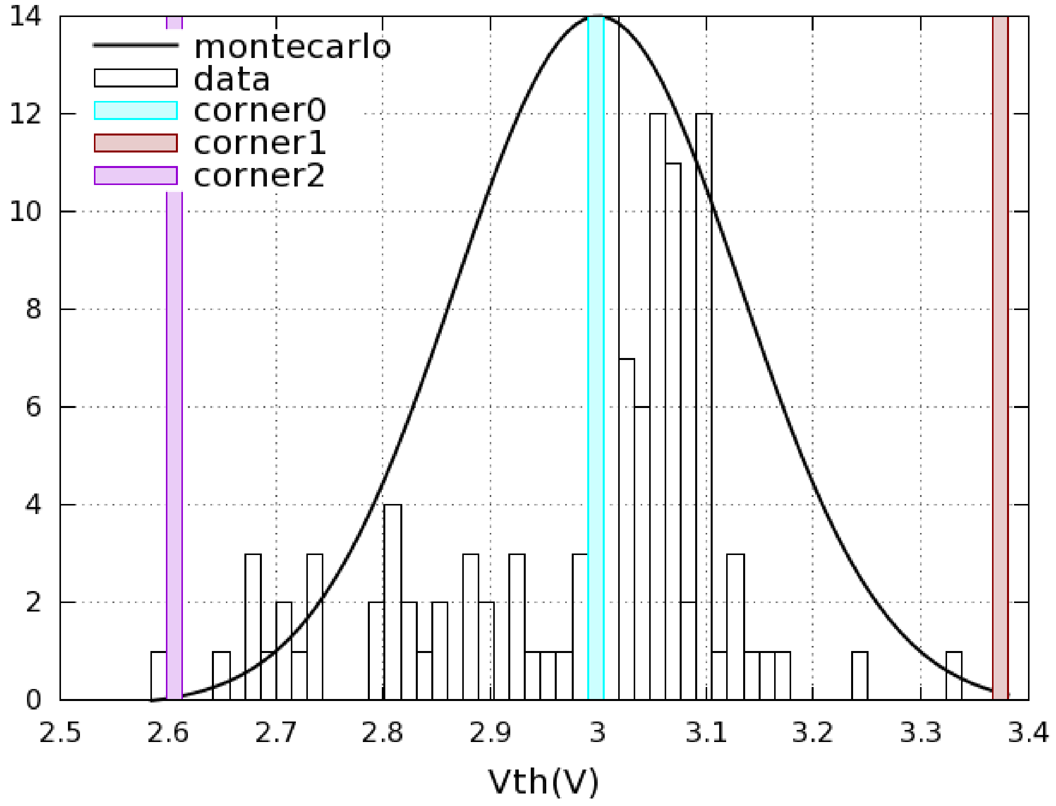
Variances in Electrical Performances Generated from Characterization Data

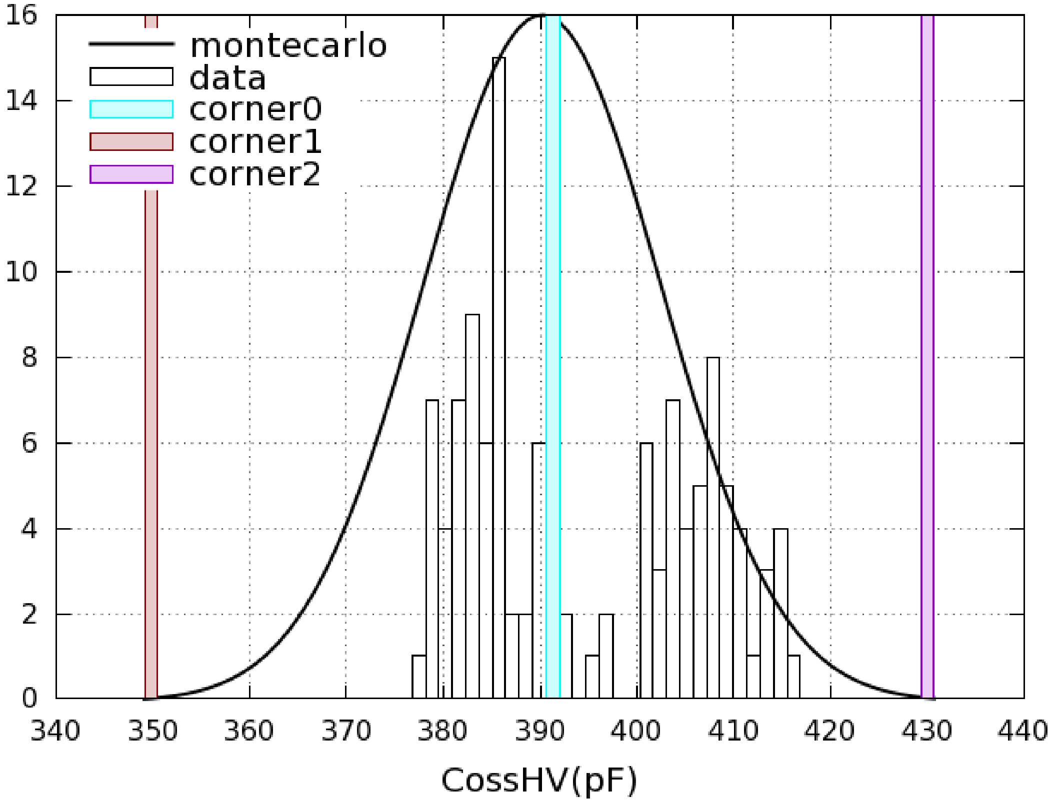
- Characterization (CZ) measurements of Electrical Specifications (E) performed on a small sample size.
- 4 Lots with 30 samples each = 120 points is enough to establish the physical correlations among the E.
- Variances (σ^2) of electrical performances E are established for the BPV solve.

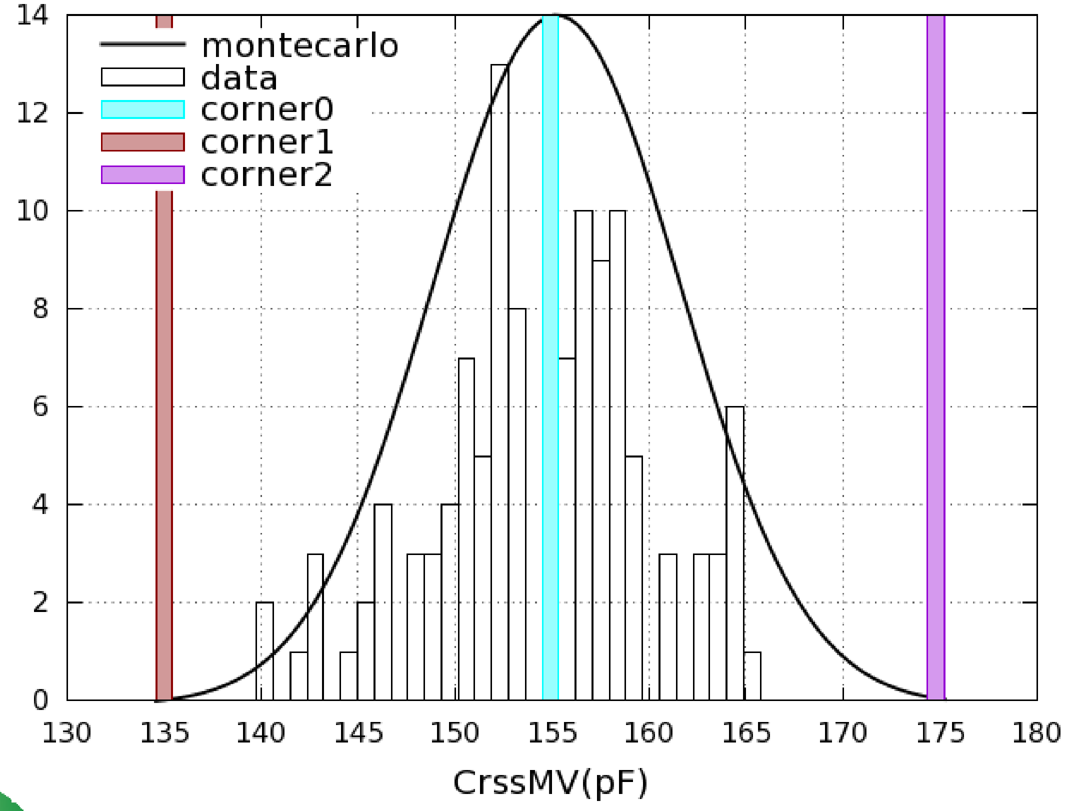
E	corner2	corner0	corner1	Description
Vth	0.8665	1	1.1335	Vth @ 5mA
RDSonhi	0.7879	1	1.2121	RDSon @ VG=20, ID=20
RDSonlo	0.7406	1	1.2594	RDSon @ VG=15, ID=5
BVdss	0.9073	1	1.0927	BV @ 100uA
CissHV	1.0814	1	0.9186	Ciss @ VD=20V
CrssLV	1.0669	1	0.9331	Crss @ VD=1mV
CrssMV	1.1092	1	0.8908	Crss @ VD=5V
CrssHV	1.1985	1	0.8015	Crss @ VD=20V
CossLV	1.032	1	0.968	Coss @ VD=1mV
CossHV	1.0902	1	0.9098	Coss@ VD=20V
Qg	1.0906	1	0.9094	Qg @ VDS=800, VG=20, ID=20

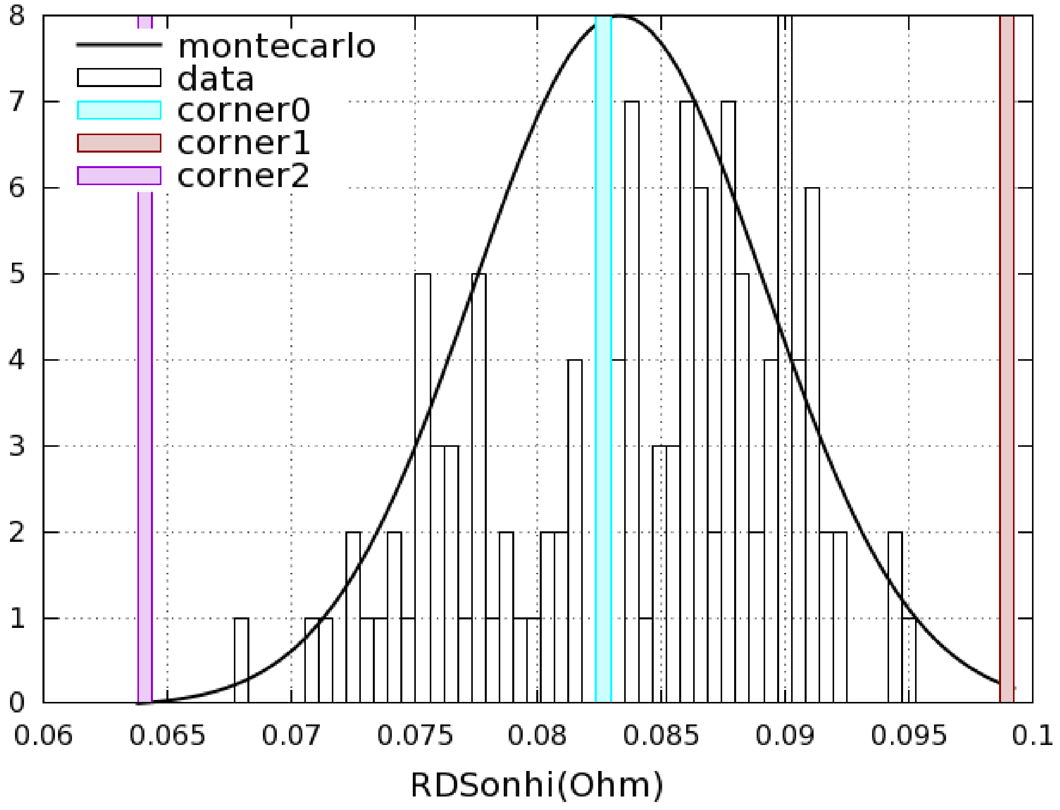
Sample Corner / Monte Carlo Gaussian Plots

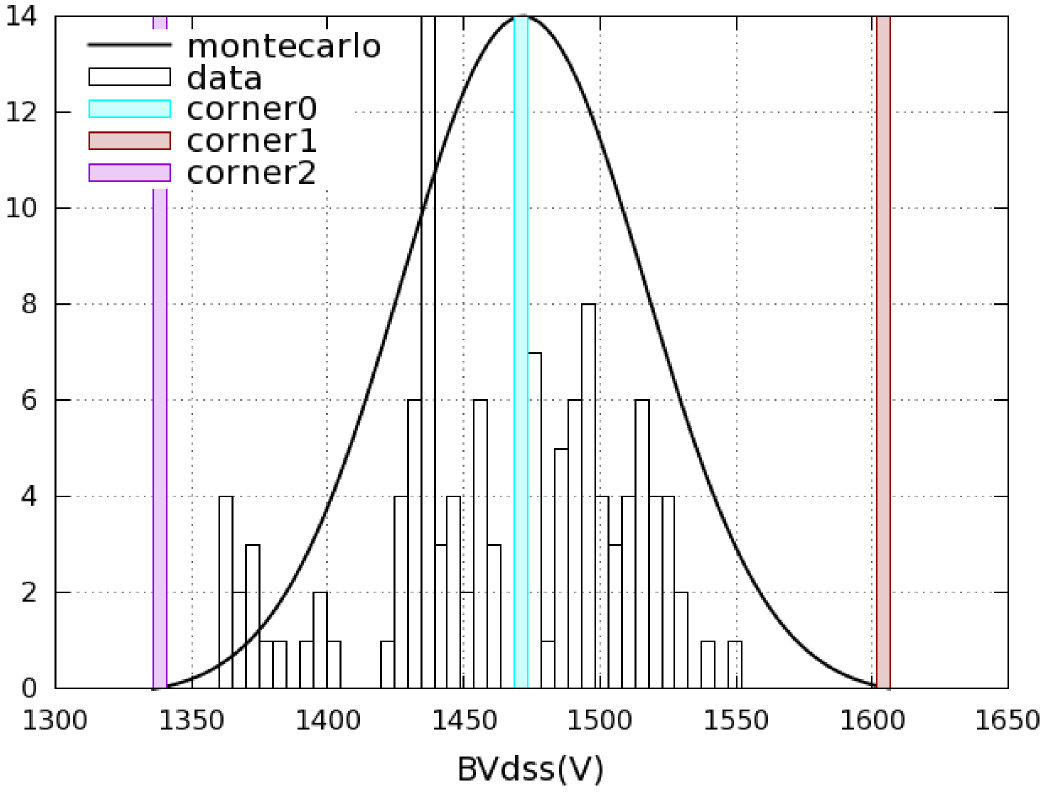
- Gaussian distribution shows up for individual lots.
- Global Gaussian distribution starting to show up.





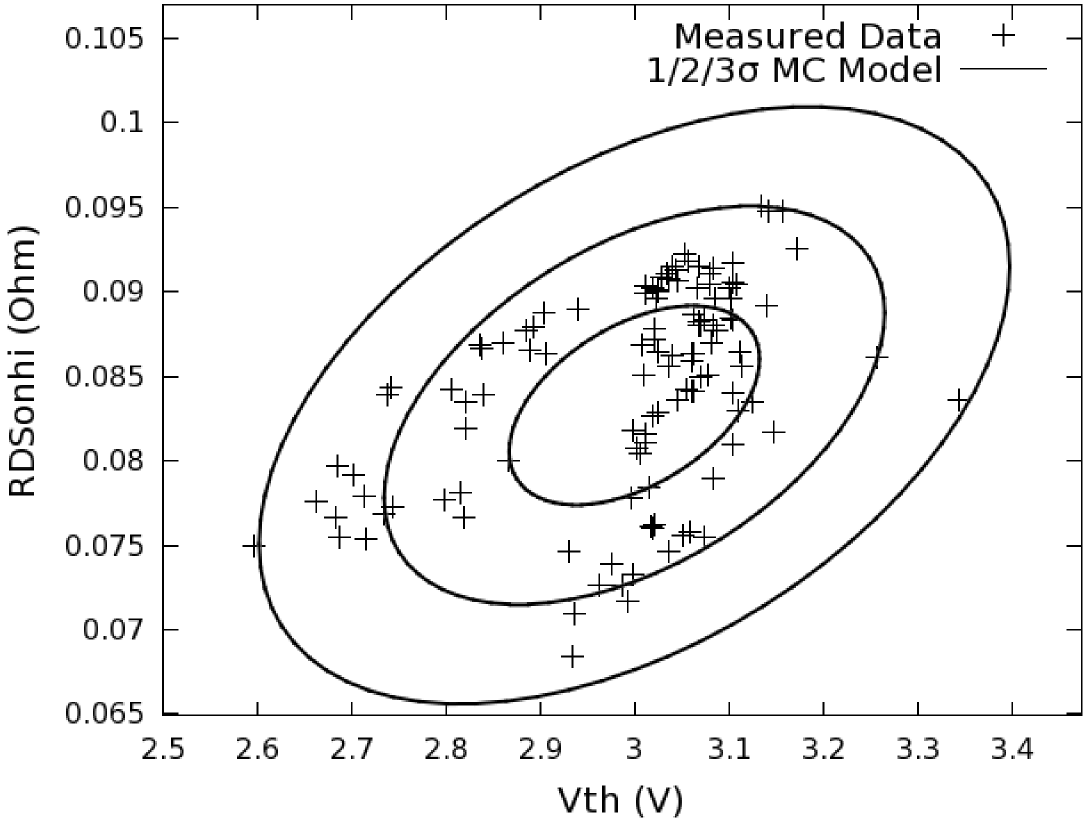


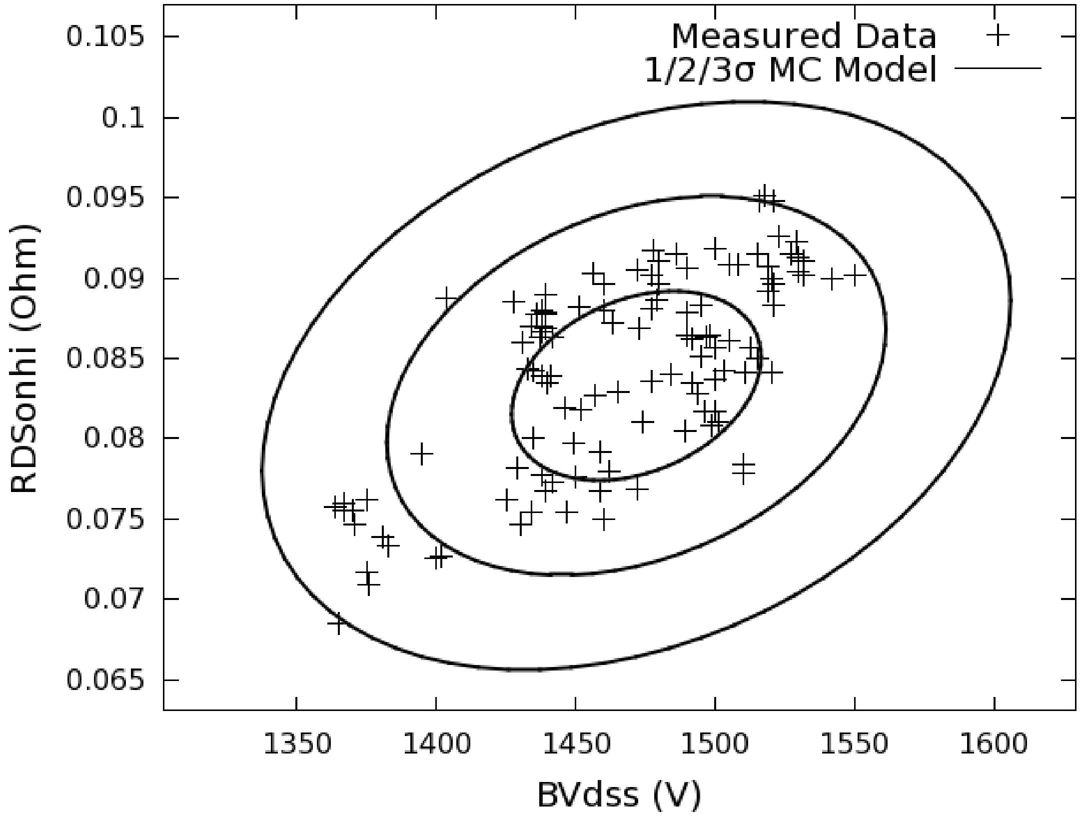


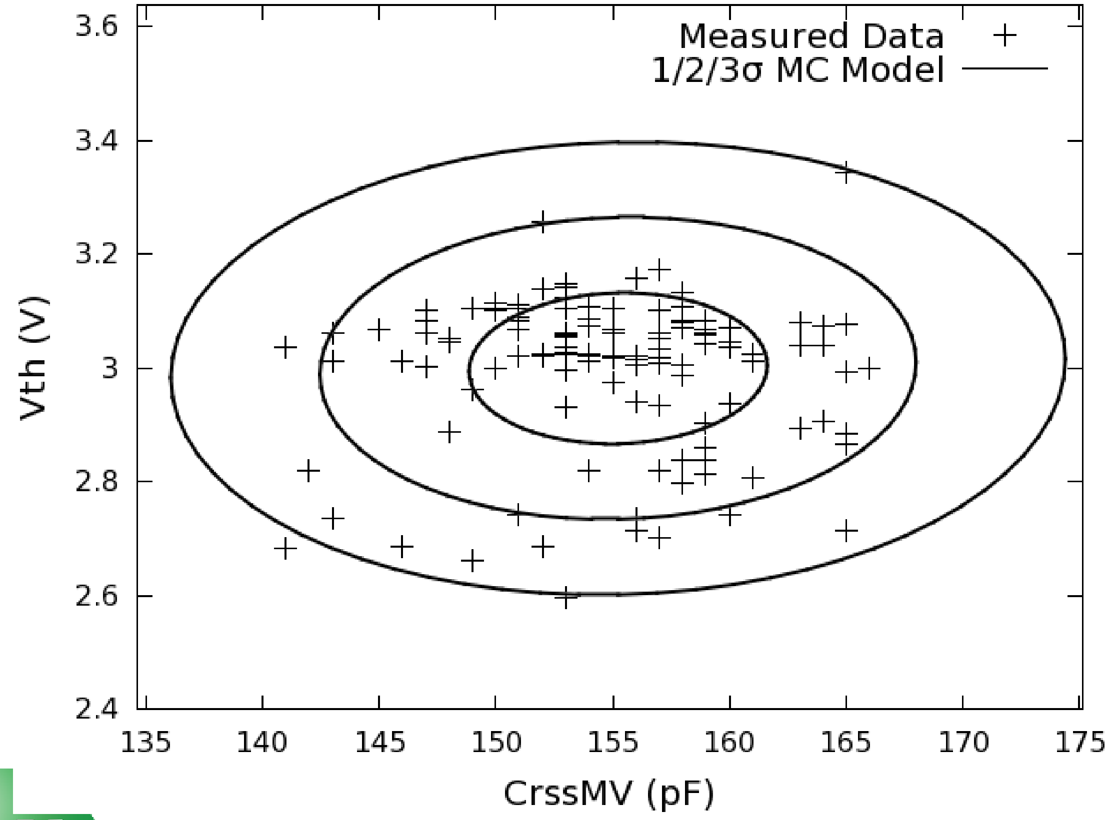


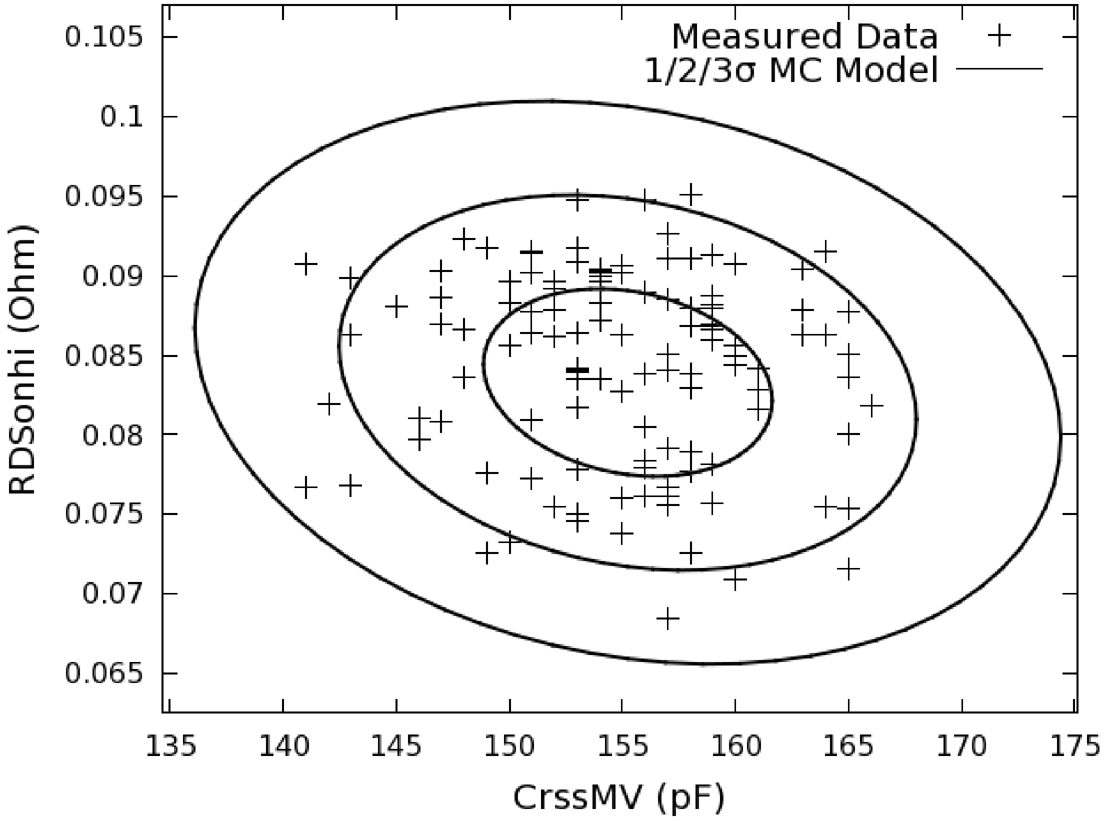
Correlation Between Electrical Performances

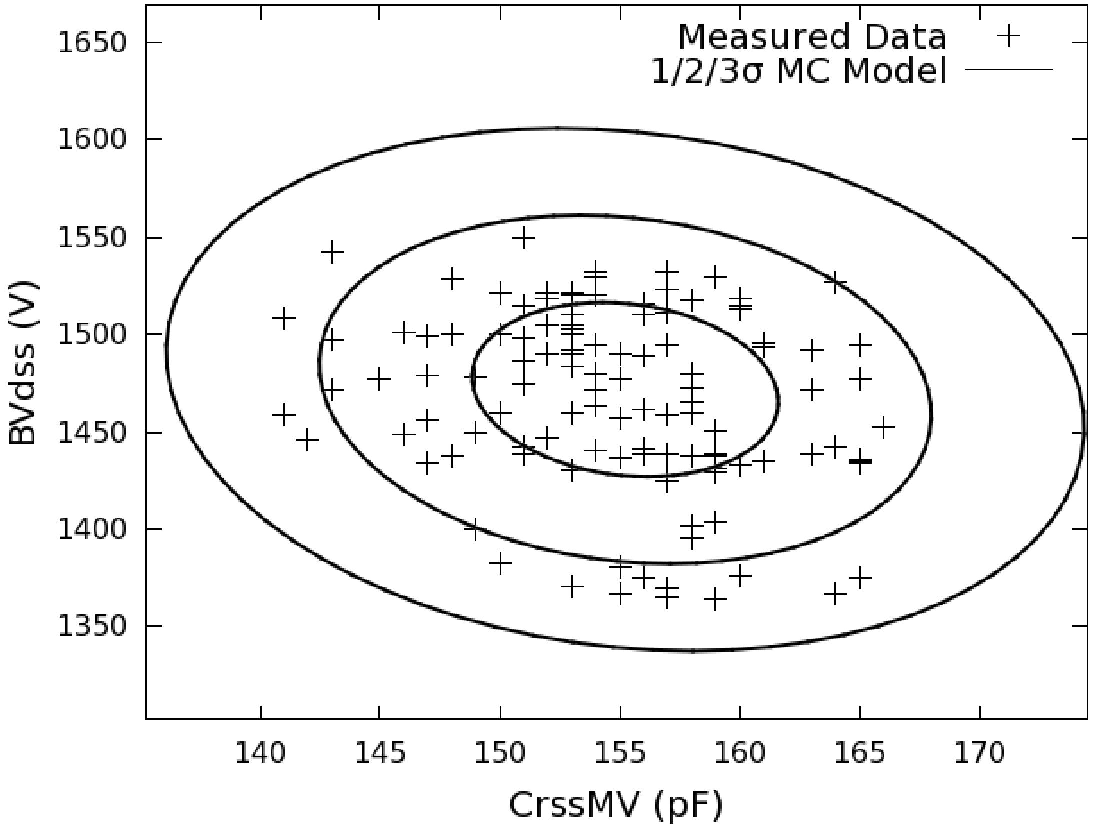
- Correlations are evident.
- There are strong or weak correlations between E.
- Physically based model catches these correlations.











Moving from Characterization to Final Test

- Final Test (FT) represents a statistically stable snapshot of the process variation.
  - FT shows wider E variation than CZ – larger statistical sample
- Why not use FT from the beginning?
  - FT data typically has no AC specs (capacitances, Q_G, etc.)
  - Incomplete BPV solution
- Physical Model:
  - Correlations between E is built into the physical model and validated through the CZ data. The results are not perfect, but reasonable.
  - The model physics are relied upon to predict the “virtual” FT AC parameter variation.

Sigma Expansion from Characterization to Final Test

Steps:

1. FT data shows larger sigma, calculate ratios as:

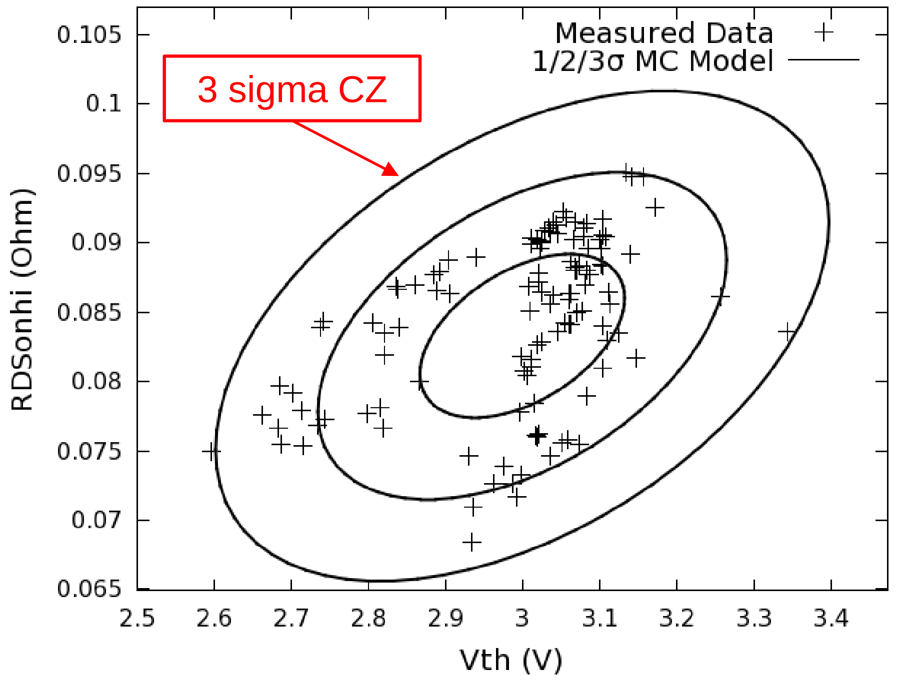
   BV_{dss}: 1.78 (=16.49/9.27)

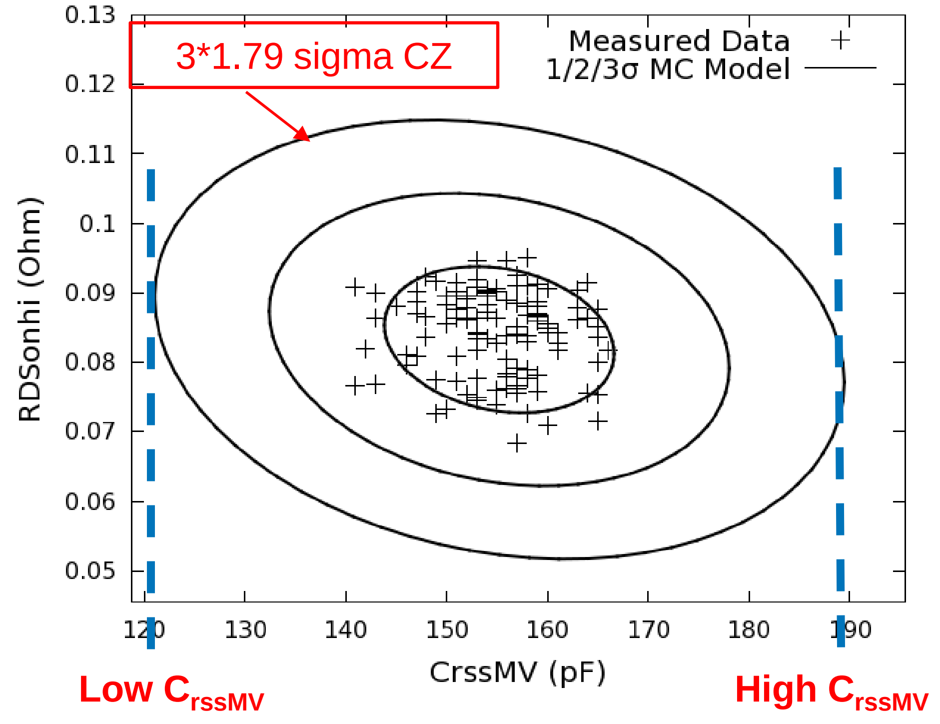
   V_{th}: 1.79 (=23.85/13.35)

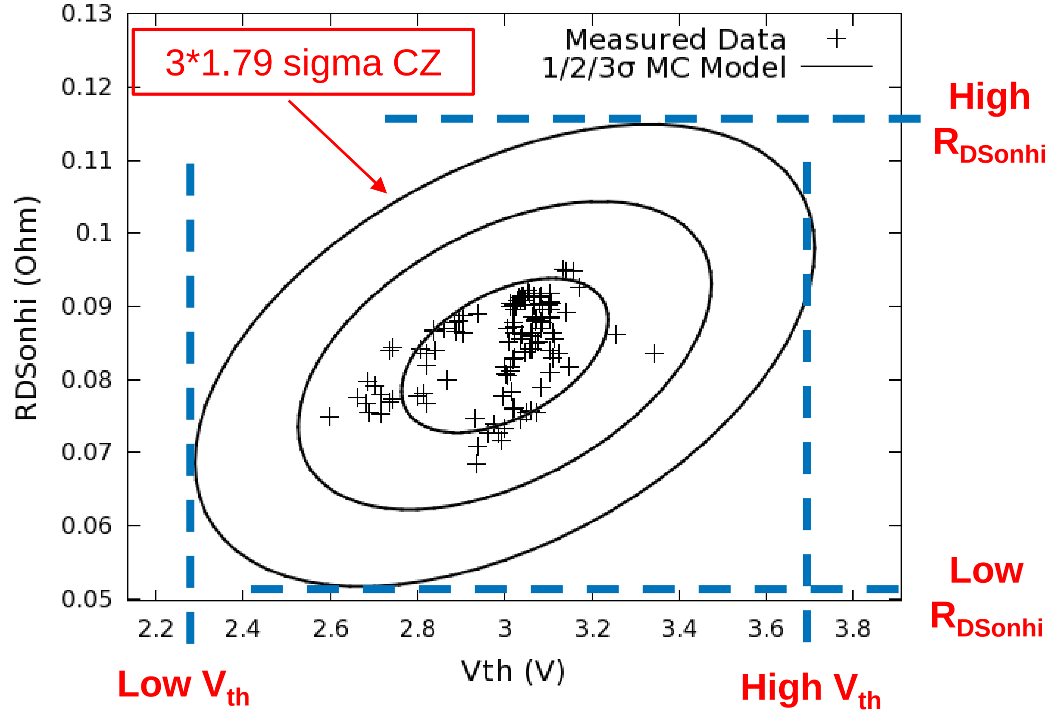
   R_{DSonhi}: 1.51 (=32.03/21.21)

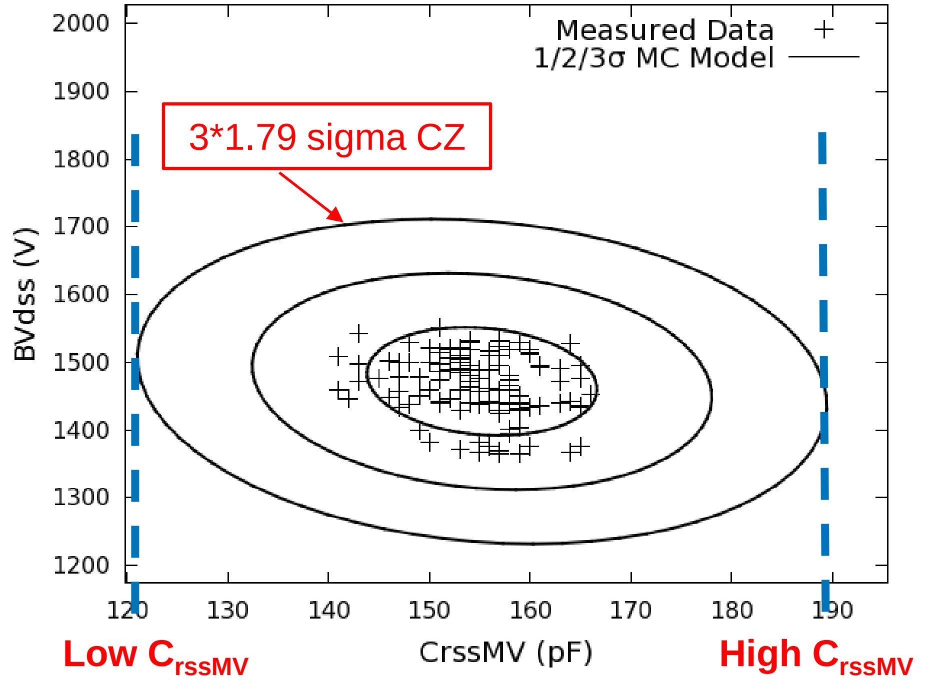
2. Largest ratio of 1.79 is used to expand the E variation to match FT. So, 3 sigma of FT is equal to 5.37 (=1.79*3) sigma of CZ.
3. Low and high E values are extracted from the simulated correlation plots to establish virtual E spec limits for AC parameters and some missing DC parameters in FT needed for BPV.
   - Plots on the right show consistent C_{rssMV} spec generation from R_{DSonhi} and BV_{dss} correlation.
4. A new set of BPV models aligned to the complete E from FT are generated.

Parameter	Characterization Lab (CZ) : ~120 pts			Final Test (FT) : ~18350 pts			FT/CZ ratio
	median	stdev	3*std/median	median	stdev	3*std/median	
BVdss	1472	45.49	9.27%	1467	80.67	16.49%	1.78
Vth	3.02	0.135	13.35%	2.88	0.229	23.85%	1.79
RDSonhi	0.0856	0.0061	21.21%	0.0779	0.0083	32.03%	1.51







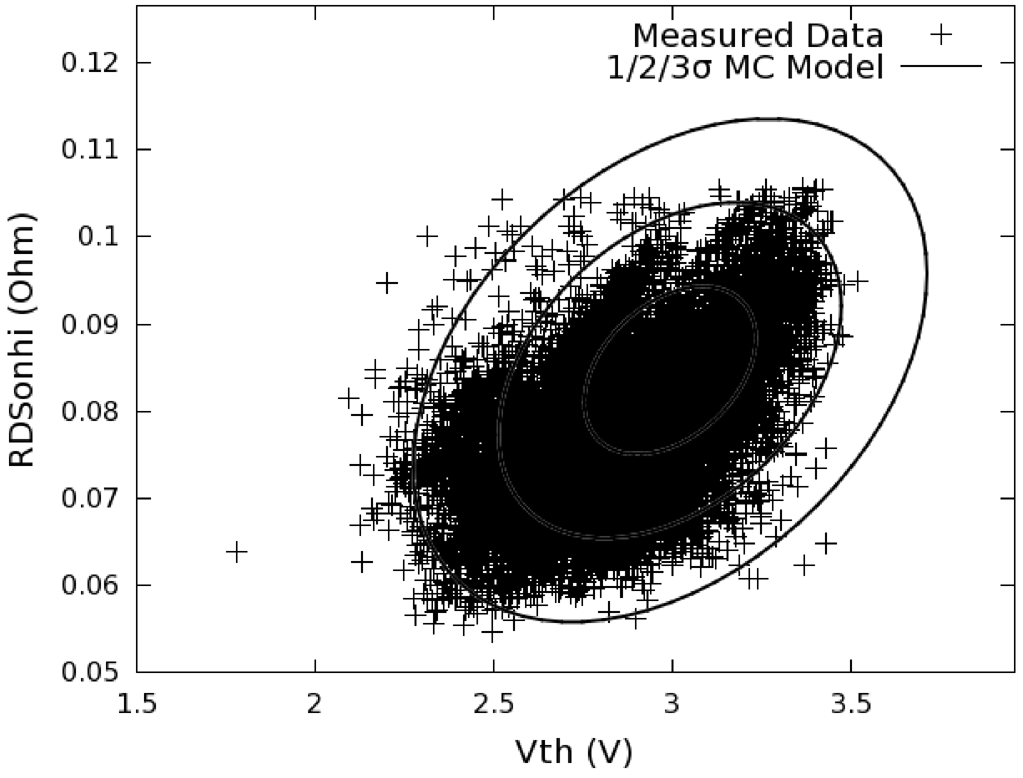


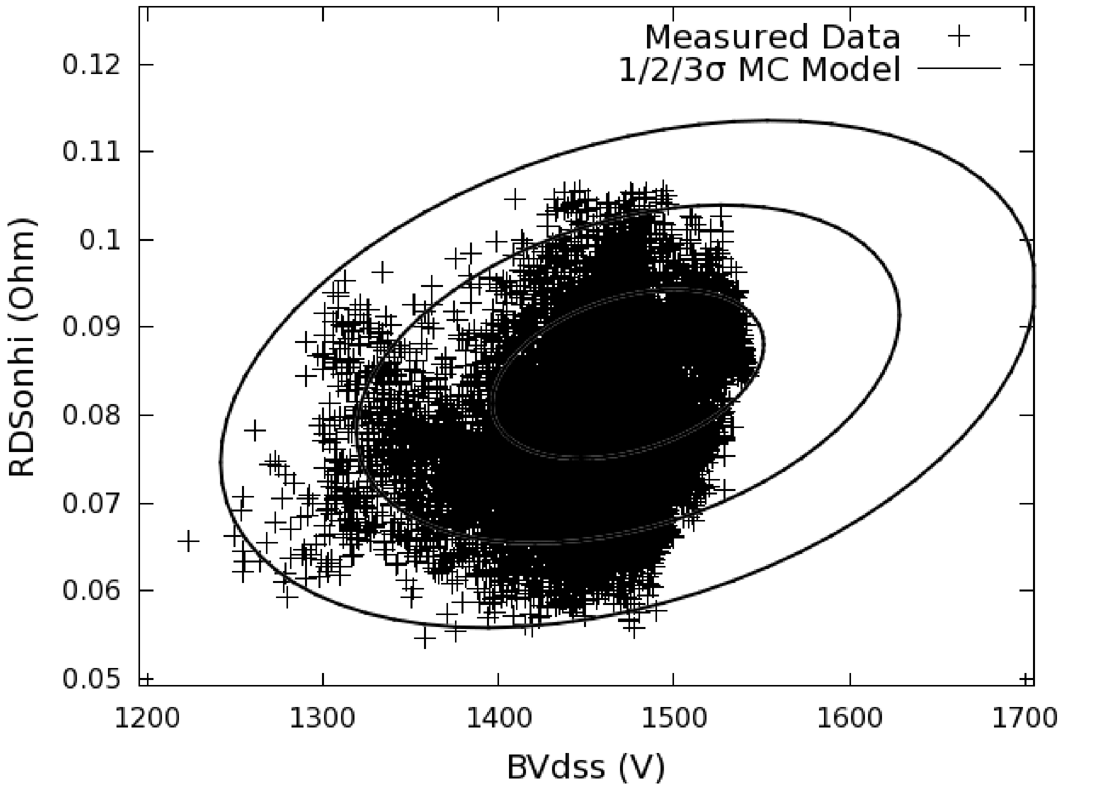
Corner / MC Correlation Plots with Final Test data

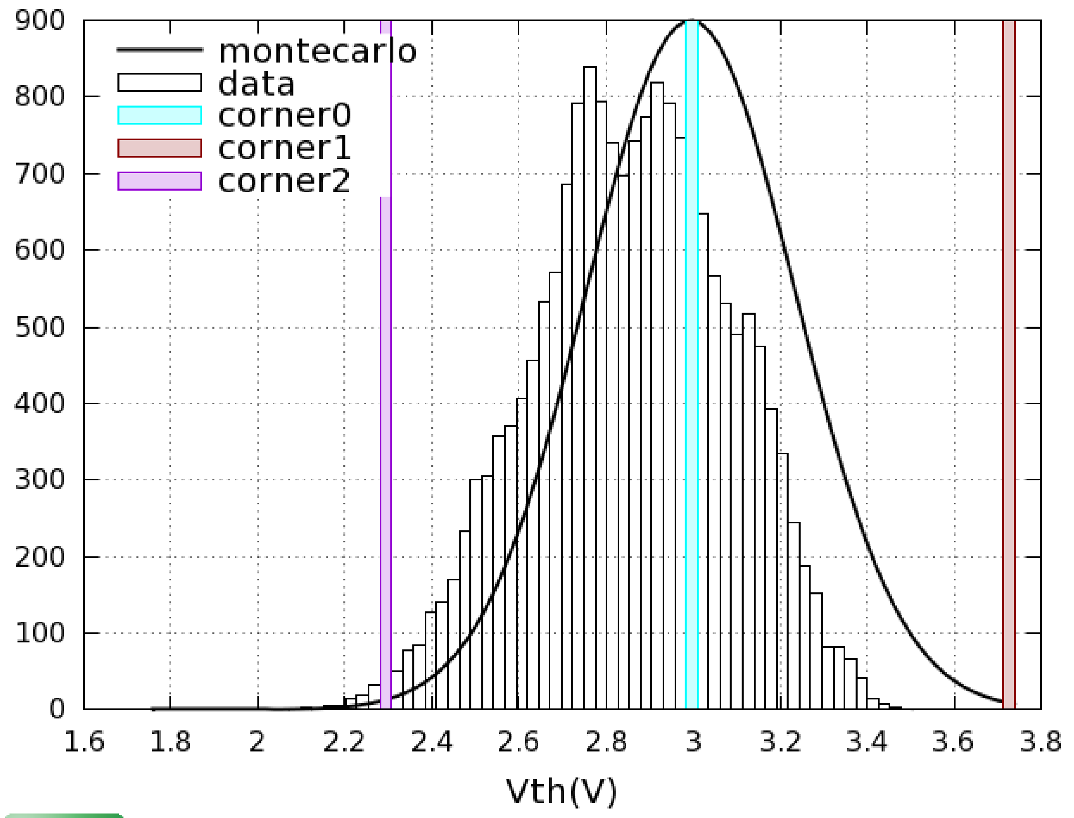
E variation widened for FT

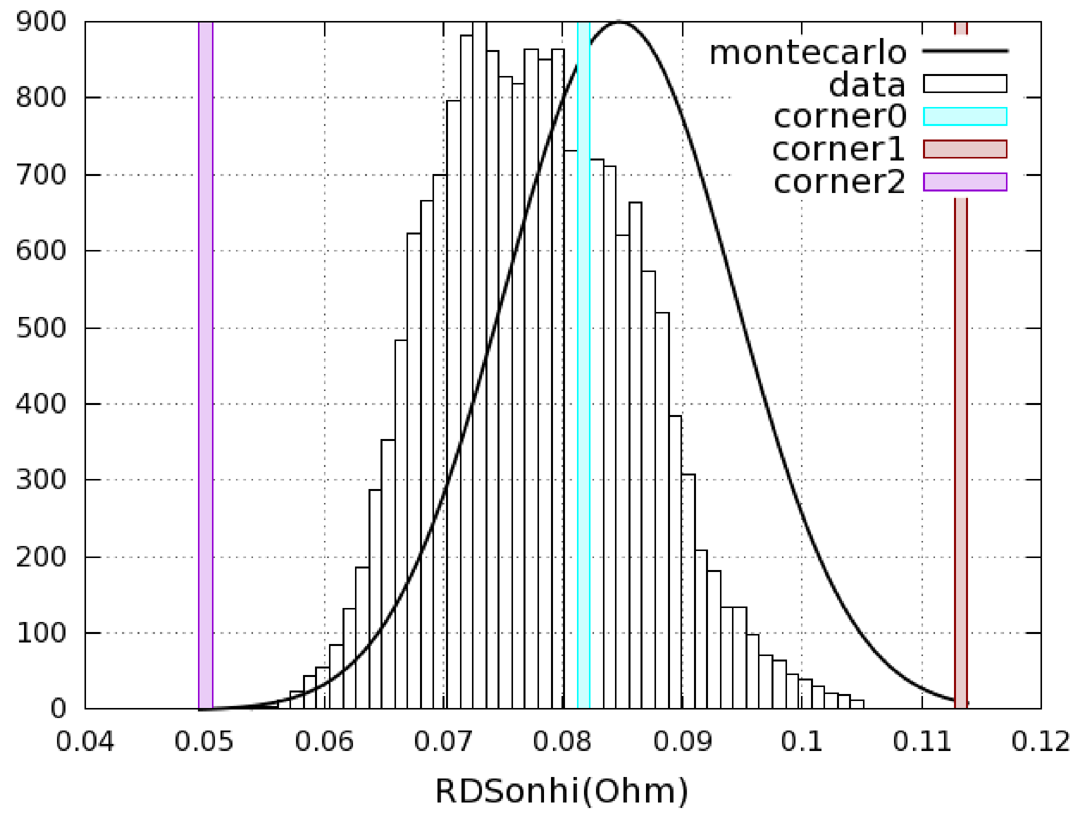
- Model is centered to CZ median
- Mean of CZ and FT don't match perfectly

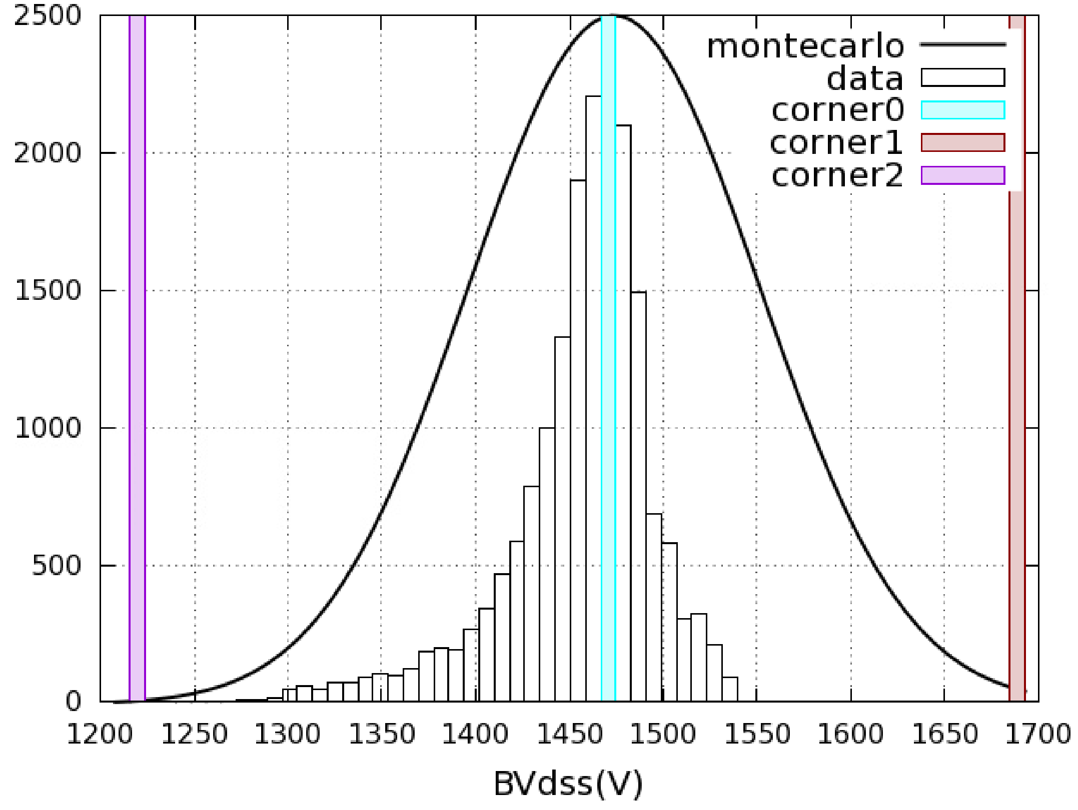
E (FT)	corner2	corner0	corner1
Vth	0.758	1	1.242
RDSonhi	0.617	1	1.383
RDSonlo	0.561	1	1.439
BVdss	0.837	1	1.163
CissHV	1.136	1	0.864
CrssLV	1.122	1	0.878
CrssMV	1.221	1	0.779
Crss20	1.217	1	0.783
CrssHV	1.081	1	0.919
CossHV	1.143	1	0.857
Qg	1.160	1	0.840











*Asymmetrical BV_{dss} distribution not accounted for in the models.

BVdss data shows asymmetric distribution due to leakage effects.

Conclusion

- Modern day power electronic design requires accurate and aggressive electrical specifications to eliminate over design.
- Very important in SiC MOSFET due to material supply and costs
- BPV based SPICE models accurately represent the real process variations throughout a technology manufacturing lifetime.
- Techniques presented allow for datasheet AC parameter limit setting in the absence of production level AC data.
- The proposed models enable circuit designers to produce optimized, robust, high yield products through simulation.

Thank you