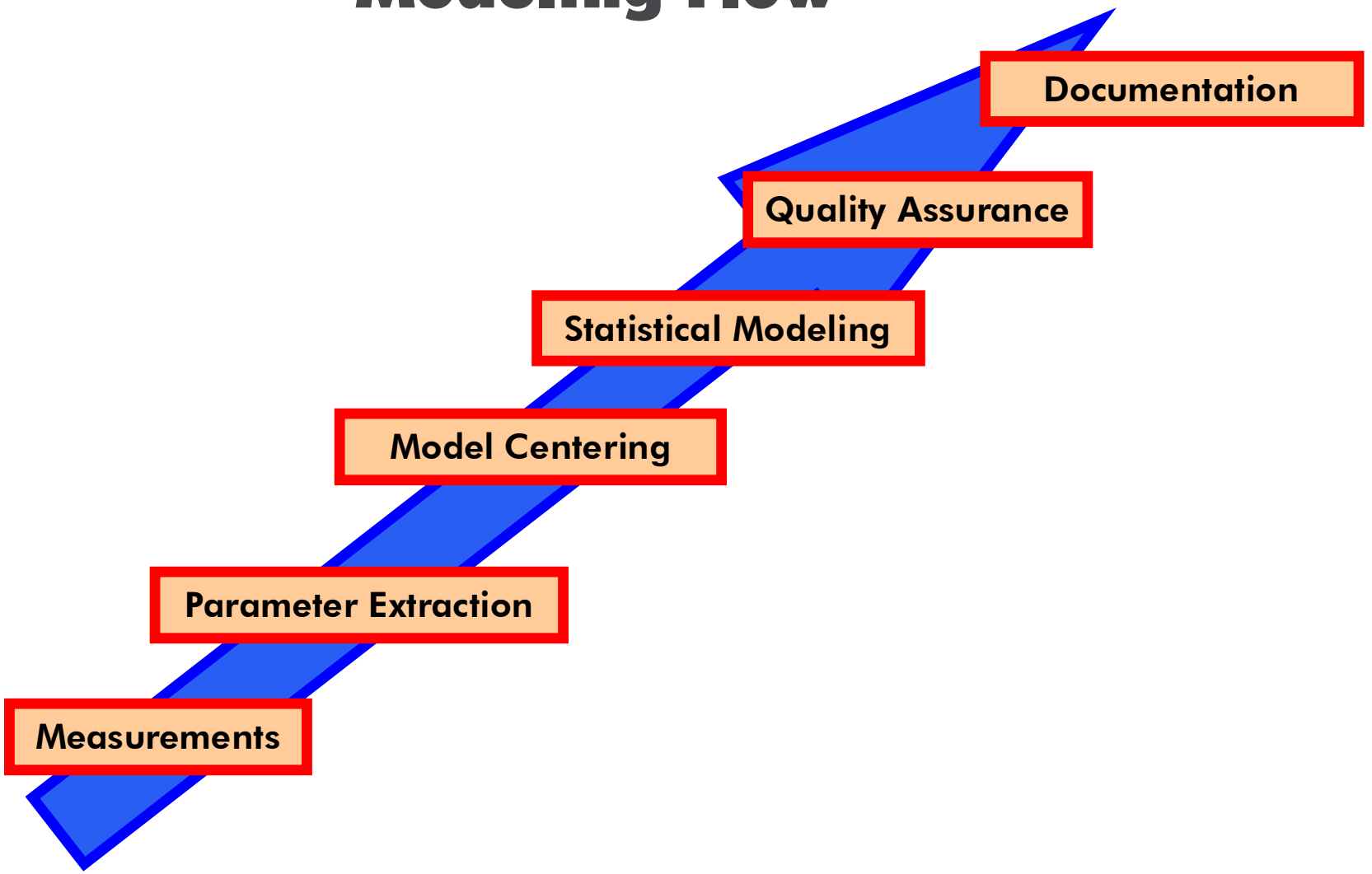
Versatile Simulator-independent MOSFET Extractor

Thomas Gneiting, AdMOS GmbH (thomas.gneiting@admos.de)
Franz Sischka, Agilent Technologies (franz.sischka@agilent.com)

AdMOS

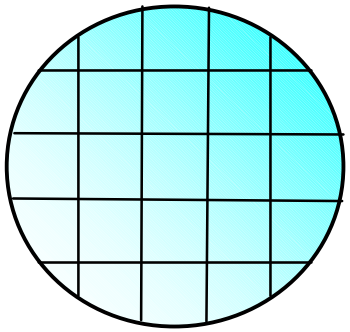
Agilent Technologies

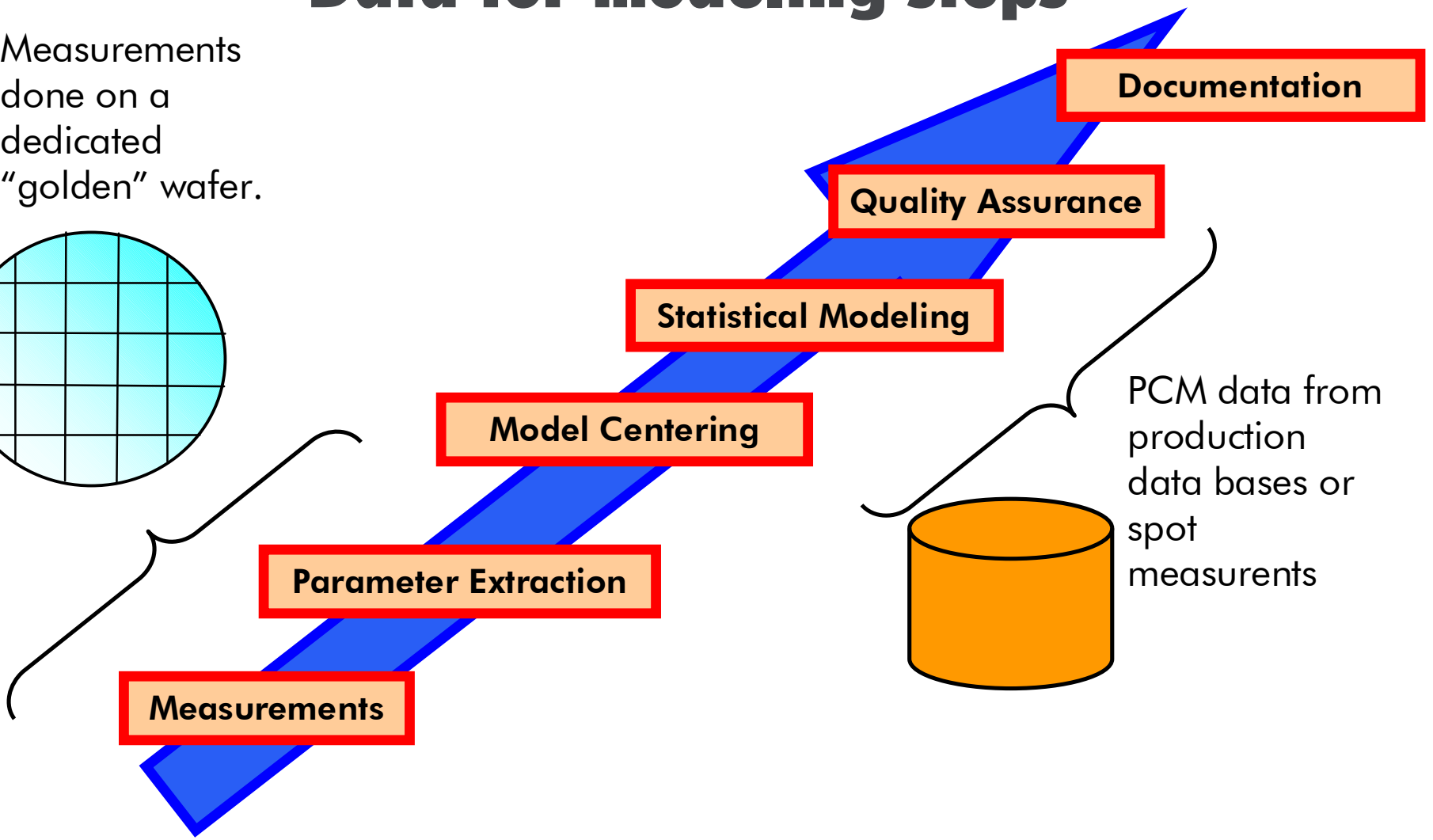
Modeling Flow



Data for modeling steps

Measurements done on a dedicated "golden" wafer.





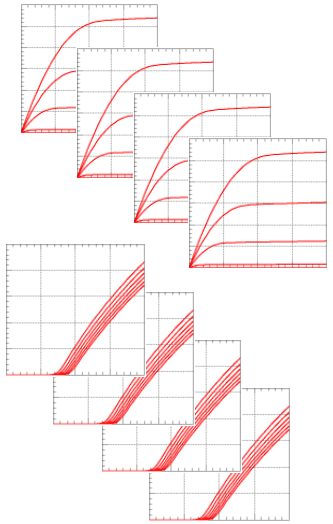
PCM data from production data bases or spot measurents

AdMOS

Agilent Technologies

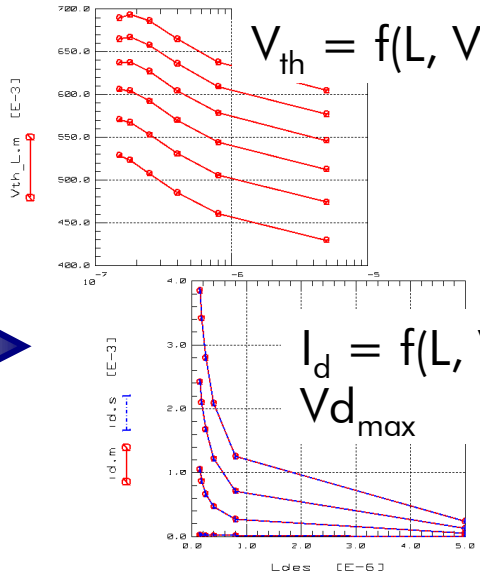
Advanced data representation concept

Collect data of up to 30 test structures during measurement phase of:



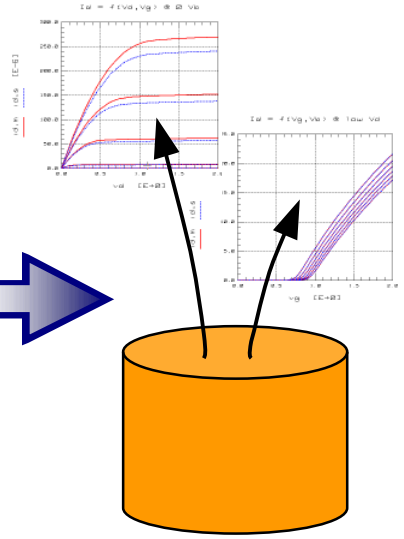
I-V, C-V curves etc.

Generate condensed data arrays for e.g.:



- **Extraction of geometry dependant effects and parameters**
- **Meaningful, PCM like, data representation**

Individual device data display:



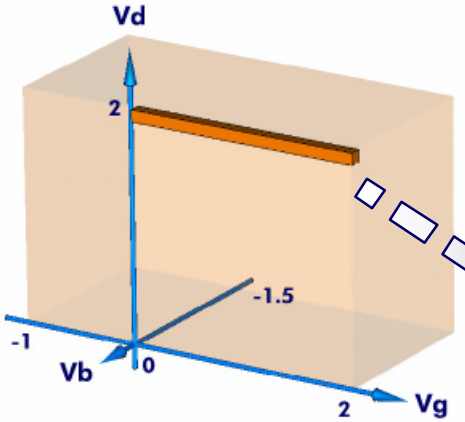
Load curves from a database if necessary.

AdMOS

Agilent Technologies

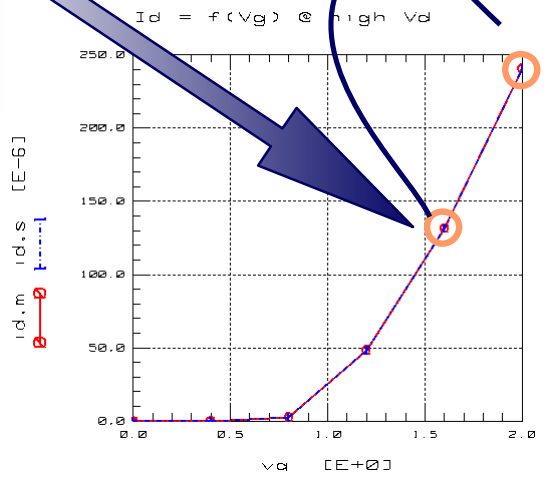
Advanced data representation concept

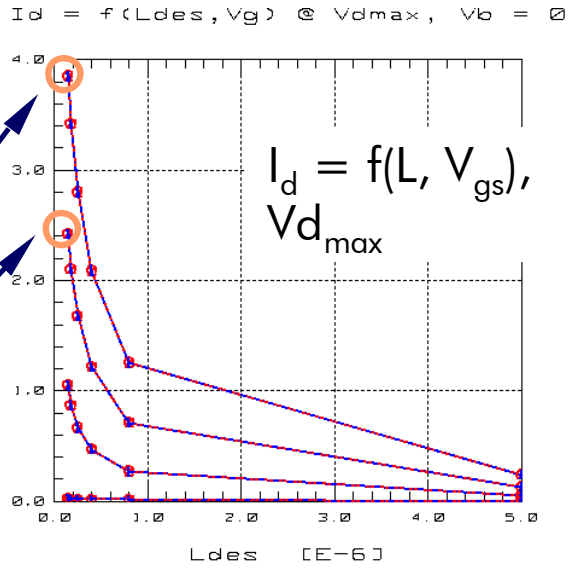
Terminal voltage space for one device:



Cut out a representative **sub-region** for certain effects.

Combine voltage sub-region with length-scaling





$I_d = f(L, V_{gs})$, Vd_{max}

New data array with these properties:

Sweep Order	Variable
1	L_{des}
2	V_g

AdMOS

Agilent Technologies

Supported Next Generation Models

Model	Version	Model Features		
		Global	Local	Binning
PSP	102.2	x	x	x
EKV3	3.01	x	-	-
HiSIM2	2.4	x	-	x

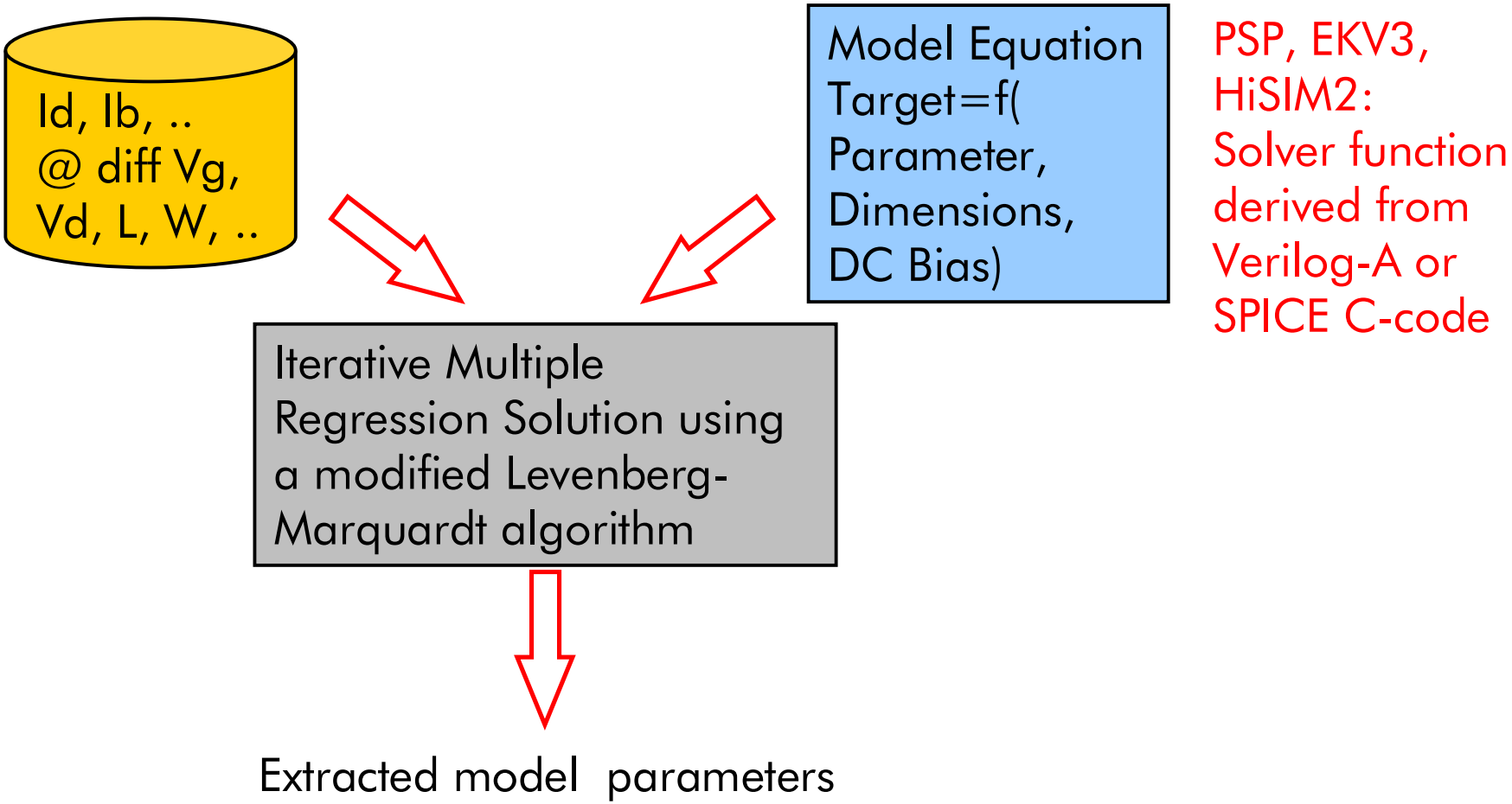
AdMOS

Agilent Technologies

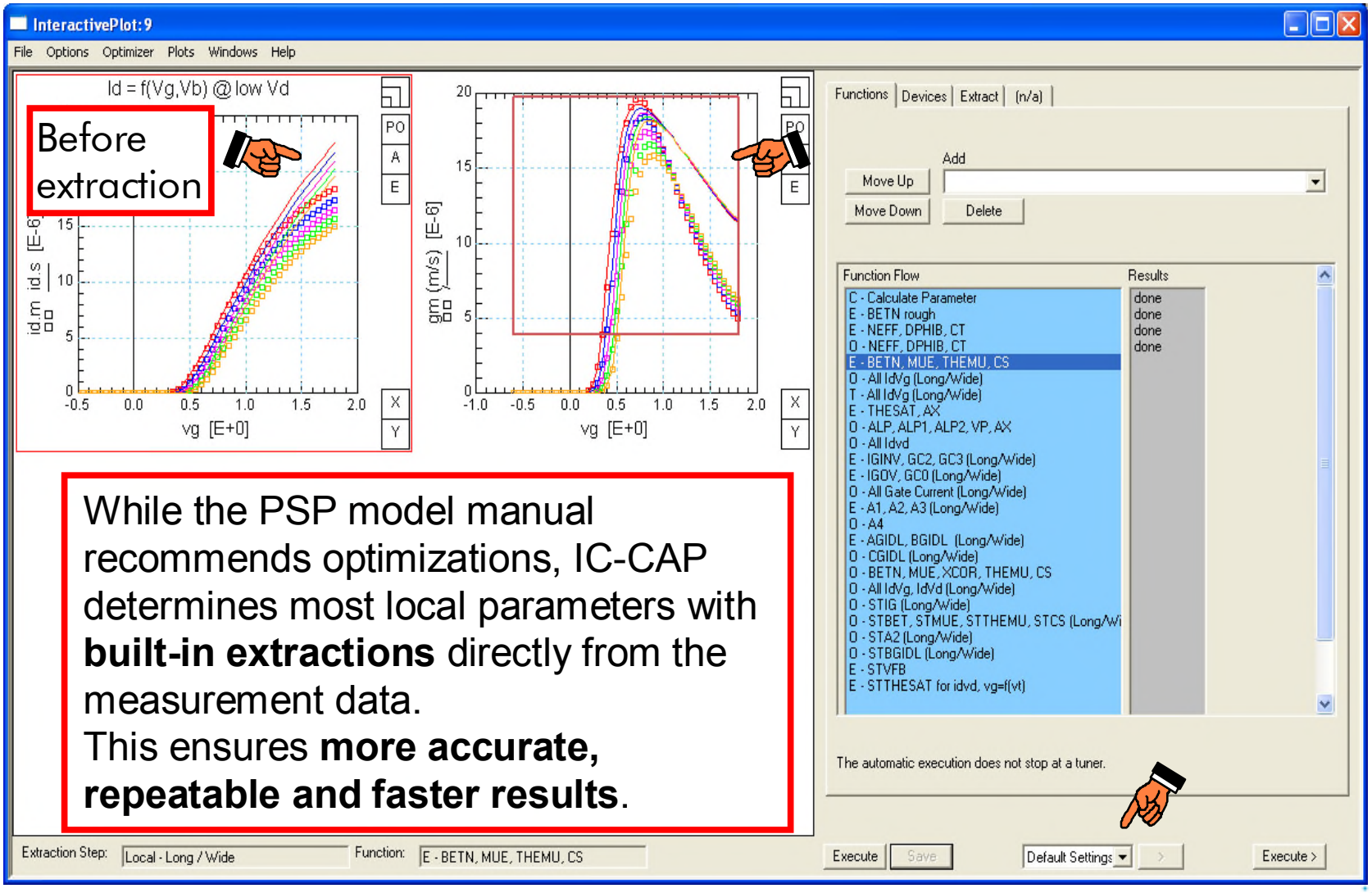
Paremeter Extraction Strategy

- The next slides show the the different methods of the parameter extraction:
  - Direct extractions
  - Manual tuners
  - Optimization on different kind of targets
- The overall organization is to have a so called „Extraction Flow“ which enables the user to compose his own sequence of different extraction functions.
- The advantage of this method is, that parameter extractions are repeatable and can be applied to different kind of processes (e.g. low VT and high VT CMOS).

Direct Parameter Extraction Method



Direct Extraction with PSP (1)

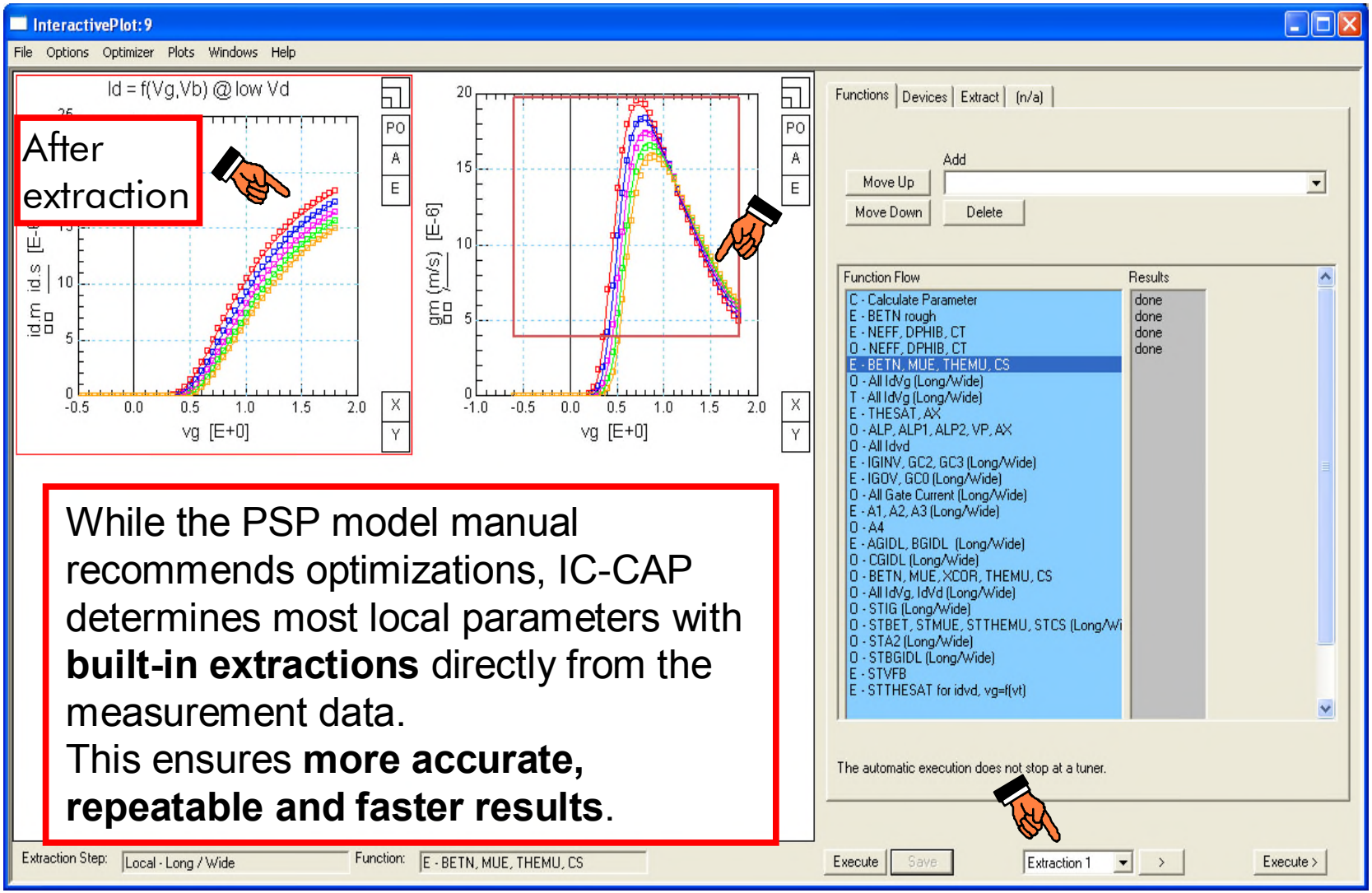


While the PSP model manual recommends optimizations, IC-CAP determines most local parameters with **built-in extractions** directly from the measurement data.
This ensures **more accurate, repeatable and faster results**.

AdMOS

Agilent Technologies

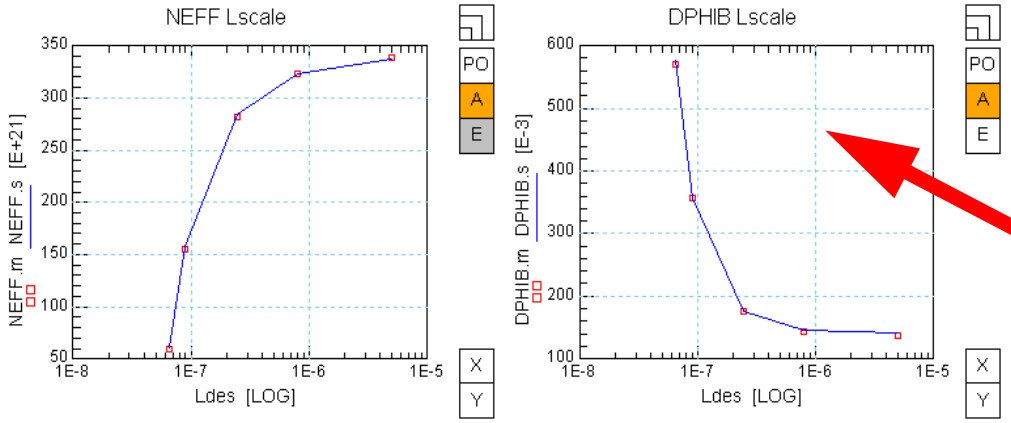
Direct Extraction with PSP (2)

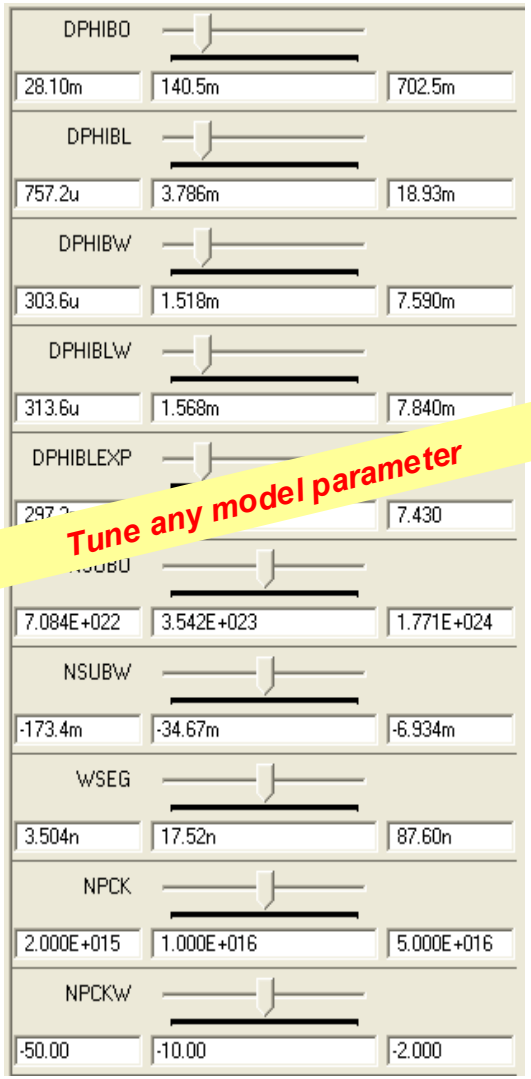


Agilent Technologies

Manual Tuning of Models (Example: PSP)

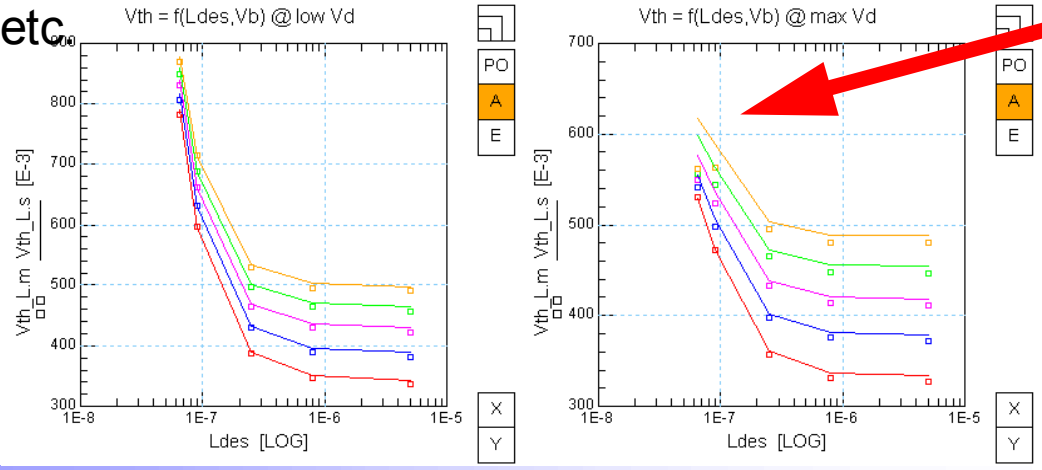
- **Show the scaling of more than one local parameter simultaneously, e.g. DPHIB and NEFF to model Vth**





Tune any model parameter

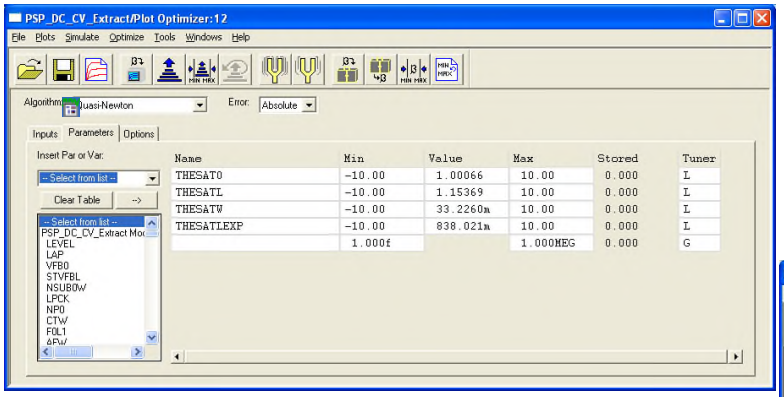
- Display in addition electrical key characteristics of the global model for several devices, e.g. Vtlin vs. L, Idlin vs. L, etc.



AdMOS

Agilent Technologies

Optimization Strategies

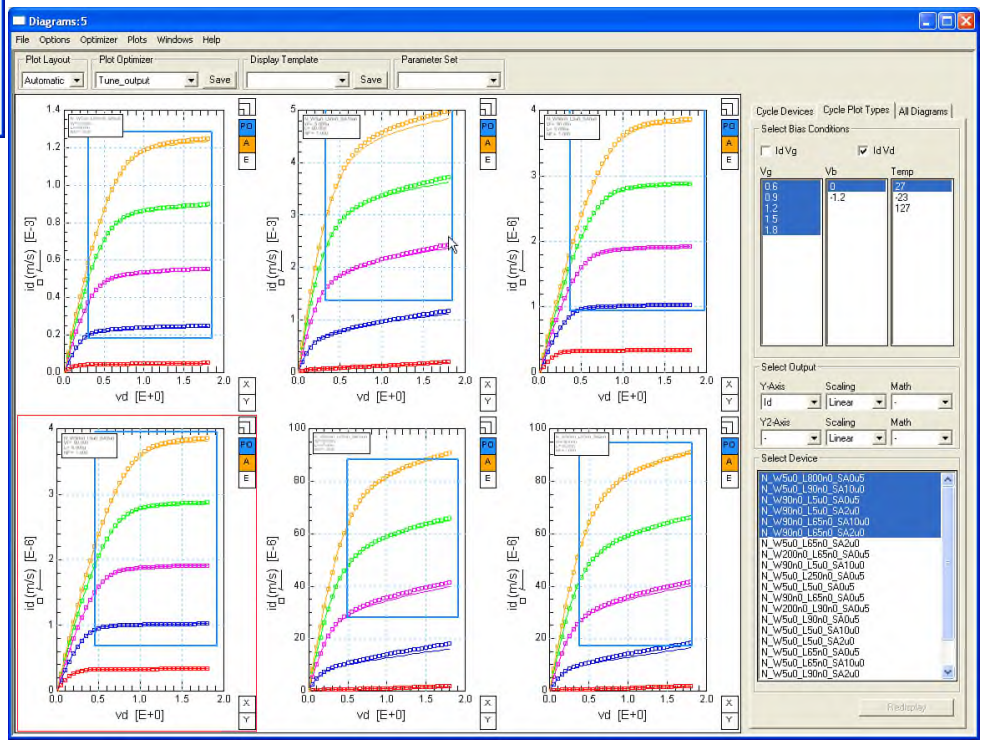


This functionality is provided by the combined data display and the Plot Optimizer.

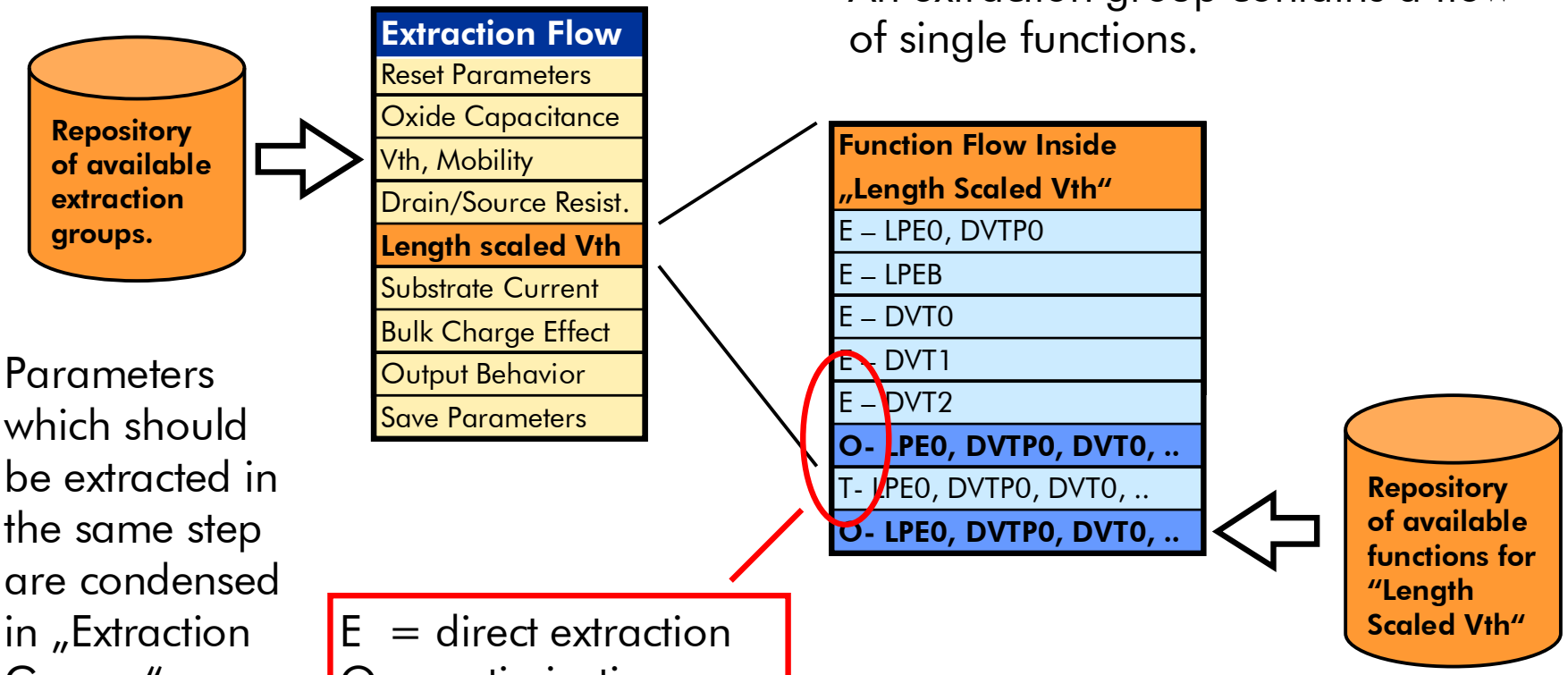
The user can select a huge variety of characteristic diagrams and can apply own graphically defined optimizers/tuners to those diagrams.

Once such an optimizer is defined, it can be reused for later extractions.

It is very likely, that it will be necessary to finetune a global model over a wide range of devices.



Configurable Extraction Flow



An extraction group contains a flow of single functions.

Parameters which should be extracted in the same step are condensed in „Extraction Groups“.

E = direct extraction
O = optimization
T = tuner

Extraction functions can be placed in any order in the function flow.

Model Centering

- MOS models are typically extracted from a Si wafer which is dedicated to perform modeling by containing special test structures. In the ideal case, this wafer should be close to the process specs.
- However, in most cases it is necessary to adjust the models in such a way, that they are representing the defined nominal behavior of a CMOS process.
- This can be done by a step called „Model Centering“ or „Target Modeling“
- Target Modeling is typically based on PCM data coming from production data bases.
- The next slides show the key steps of „Target Modeling“

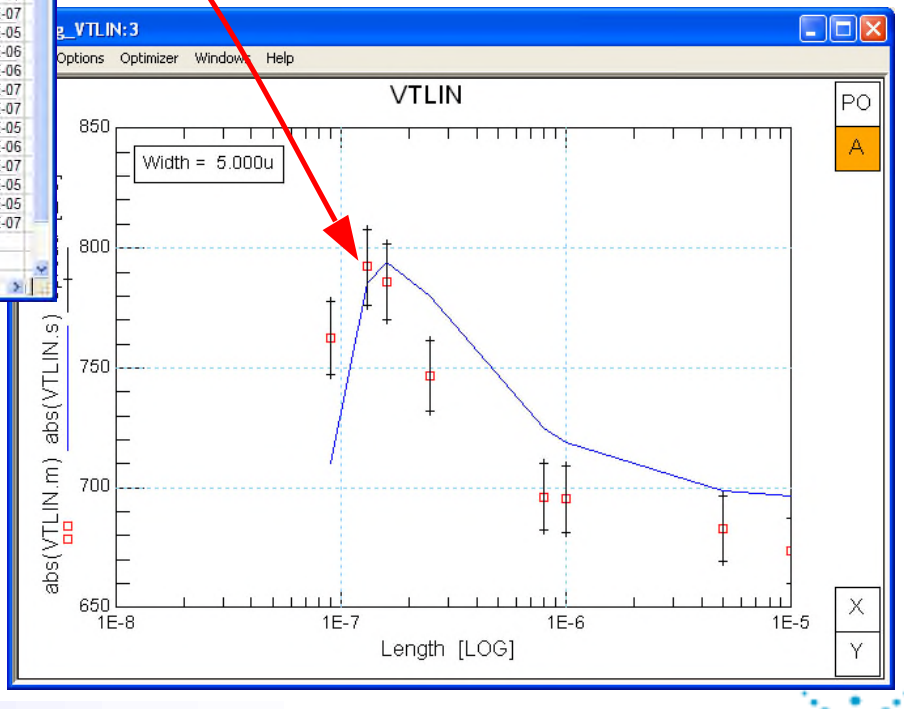
PCM Data Representation

PCM_Table2Temp

	A	B	C	D	E	M	N	O	P	Q	R
1	TYPE	ID		IP		PCM					
2	NAME	DeviceID	Name	Length	Width	ION			ILIN		
3	SUBSET					mean	max	min	mean	max	min
4	TEMP					25					
5		10	N_W 5.00(	9.00E-08	5.00E-06	0.002704	0.002785	0.002623	0.000393	0.000406	0.000381
6		11	N_W 5.00(	1.30E-07	5.00E-06	0.001515	0.00156	0.001469	0.00026	0.000268	0.000252
7		12	N_W 5.00(	1.60E-07	5.00E-06	0.001179	0.001215	0.001144	0.000213	0.000219	0.000206
8		13	N_W 5.00(	2.50E-07	5.00E-06	0.000759	0.000782	0.000737	0.000142	0.000147	0.000138
9		14	N_W 5.00(	8.00E-07	5.00E-06	0.000287	0.000296	0.000278	5.37E-05	5.53E-05	5.21E-05
10		15	N_W 5.00(	1.00E-06	5.00E-06	0.000236	0.000244	0.000229	4.42E-05	4.55E-05	4.29E-05
11		16	N_W 5.00(	5.00E-06	5.00E-06	5.10E-05	5.25E-05	4.94E-05	9.55E-06	9.84E-06	9.27E-06
12		17	N_W 5.00(	1.00E-05	5.00E-06	2.53E-05	2.61E-05	2.46E-05	4.75E-06	4.90E-06	4.61E-06
13		18	N_W 180.(	1.30E-07	1.80E-07	5.12E-05	5.28E-05	4.97E-05	8.84E-06	9.10E-06	8.57E-06
14		19	N_W 180.(	2.50E-07	1.80E-07	2.61E-05	2.69E-05	2.54E-05	4.92E-06	5.06E-06	4.77E-06
15		20	N_W 180.(	8.00E-07	1.80E-07	9.70E-06	9.99E-06	9.40E-06	1.82E-06	1.87E-06	1.76E-06
16		21	N_W 180.(	5.00E-06	1.80E-07	1.68E-06	1.73E-06	1.63E-06	3.16E-07	3.25E-07	3.06E-07
17		42	N_W 180.(	1.00E-05	1.80E-07	8.55E-07	8.81E-07	8.30E-07	1.61E-07	1.65E-07	1.56E-07
18		53	N_W 250.(	1.30E-07	2.50E-07	7.20E-05	7.42E-05	6.99E-05	1.24E-05	1.28E-05	1.20E-05
19		64	N_W 250.(	2.50E-07	2.50E-07	3.71E-05	3.82E-05	3.59E-05	6.97E-06	7.17E-06	6.76E-06
20		75	N_W 250.(	8.00E-07	2.50E-07	1.39E-05	1.43E-05	1.35E-05	2.60E-06	2.68E-06	2.53E-06
21		86	N_W 250.(	5.00E-06	2.50E-07	2.42E-06	2.49E-06	2.35E-06	4.54E-07	4.68E-07	4.41E-07
22		97	N_W 250.(	1.00E-05	2.50E-07	1.20E-06	1.24E-06	1.17E-06	2.26E-07	2.33E-07	2.19E-07
23		28	N_W 600.(	1.30E-07	6.00E-07	0.000178	0.000184	0.000173	3.07E-05	3.16E-05	2.98E-05
24		29	N_W 600.(	8.00E-07	6.00E-07	3.41E-05	3.51E-05	3.31E-05	6.39E-06	6.58E-06	6.20E-06
25		30	N_W 600.(	1.00E-05	6.00E-07	3.01E-06	3.10E-06	2.92E-06	5.66E-07	5.83E-07	5.49E-07
26		31	N_W 1.00(	1.30E-07	1.00E-06	0.000296	0.000305	0.000287	5.08E-05	5.24E-05	4.93E-05
27		32	N_W 1.00(	8.00E-07	1.00E-06	5.70E-05	5.87E-05	5.53E-05	1.07E-05	1.10E-05	1.03E-05
28		33	N_W 1.00(	1.00E-05	1.00E-06	4.94E-06	5.09E-06	4.79E-06	9.27E-07	9.55E-07	8.99E-07
29											
30											

PCM_Table2Temp

PCM data (.csv, .xls) with nominal value (mean) and statistical spread (min, max)



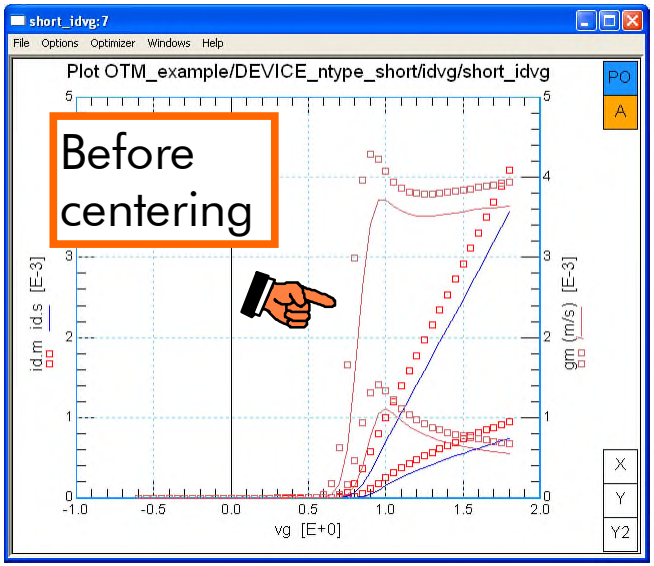
Grouping of PCM data versus dimension (W, L, SA, ..) and / or versus Temperature

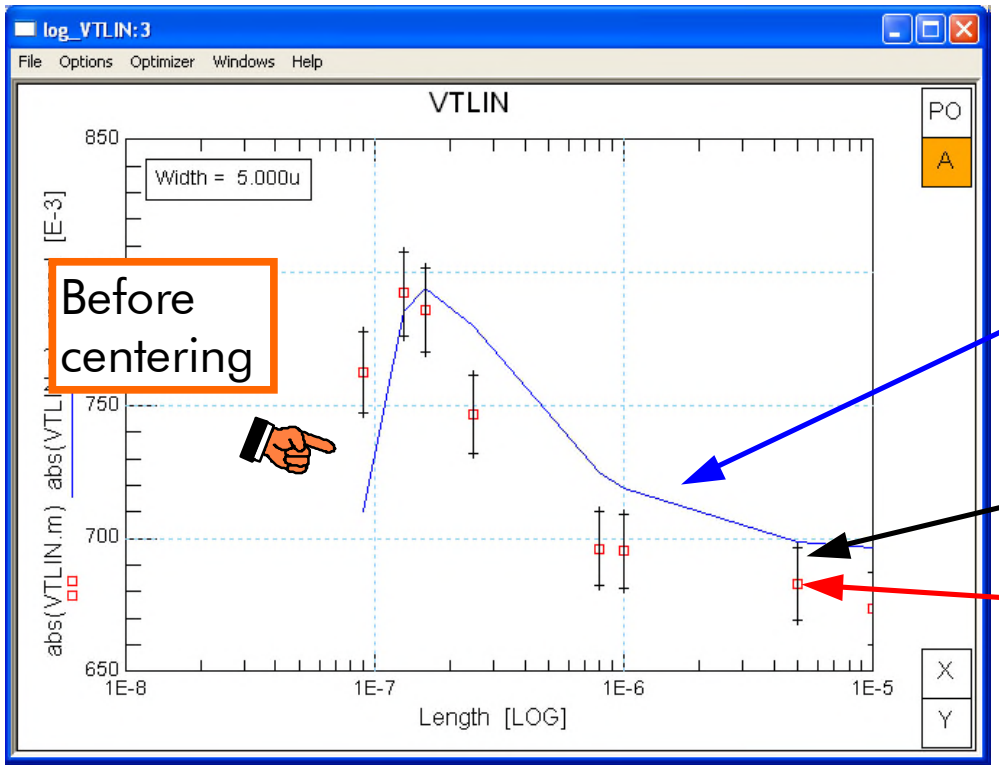
AdMOS

Agilent Technologies

Example of Model Centering

The goal of model centering is to adjust an already extracted model to a defined process while preserving the prinicipal analog behavior.





Simulation Model based on Si wafer

Statistical spread

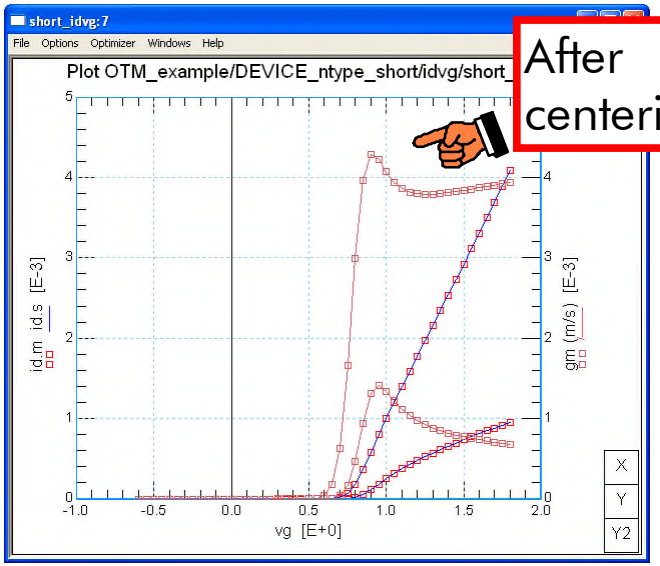
Nominal process behavior

AdMOS

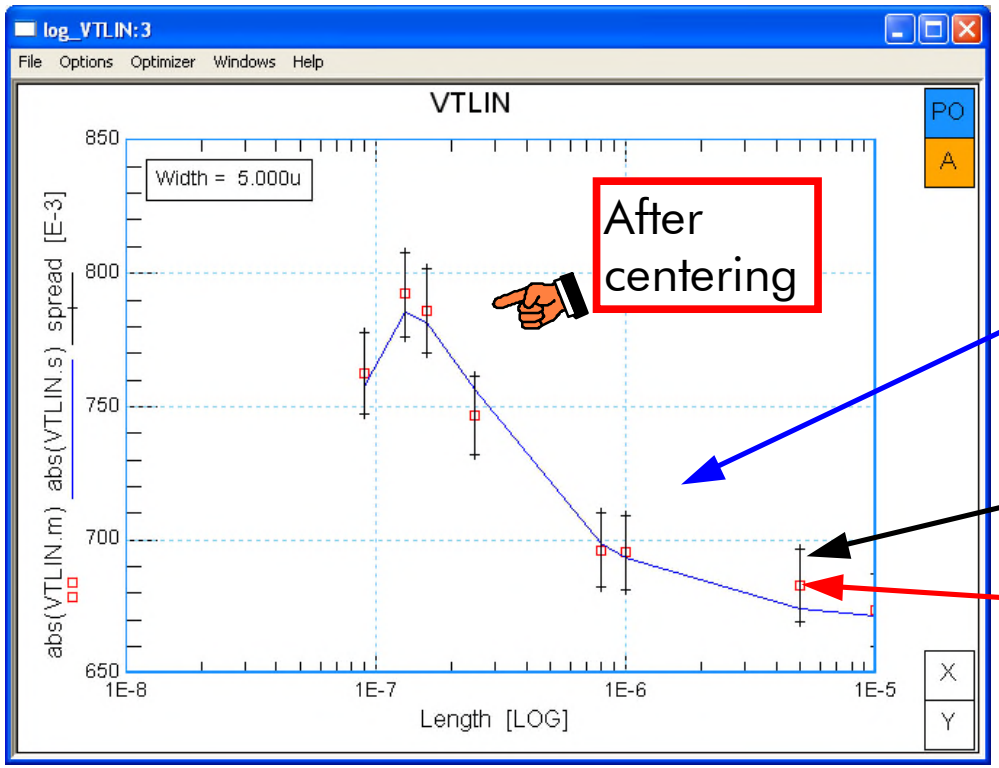
Agilent Technologies

Example of Model Centering

The goal of model centering is to adjust an already extracted model to a defined process while preserving the prinicipal analog behavior.



After centering



After centering

Simulation Model based on Si wafer

Statistical spread

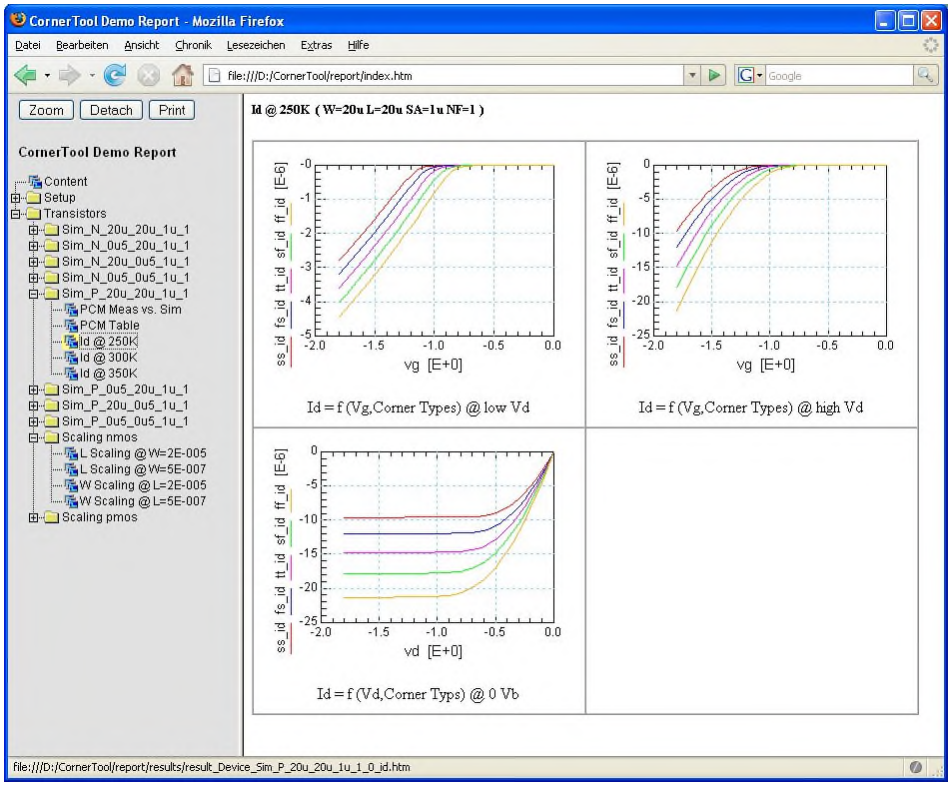
Nominal process behavior

AdMOS

Agilent Technologies

Corner Modeling

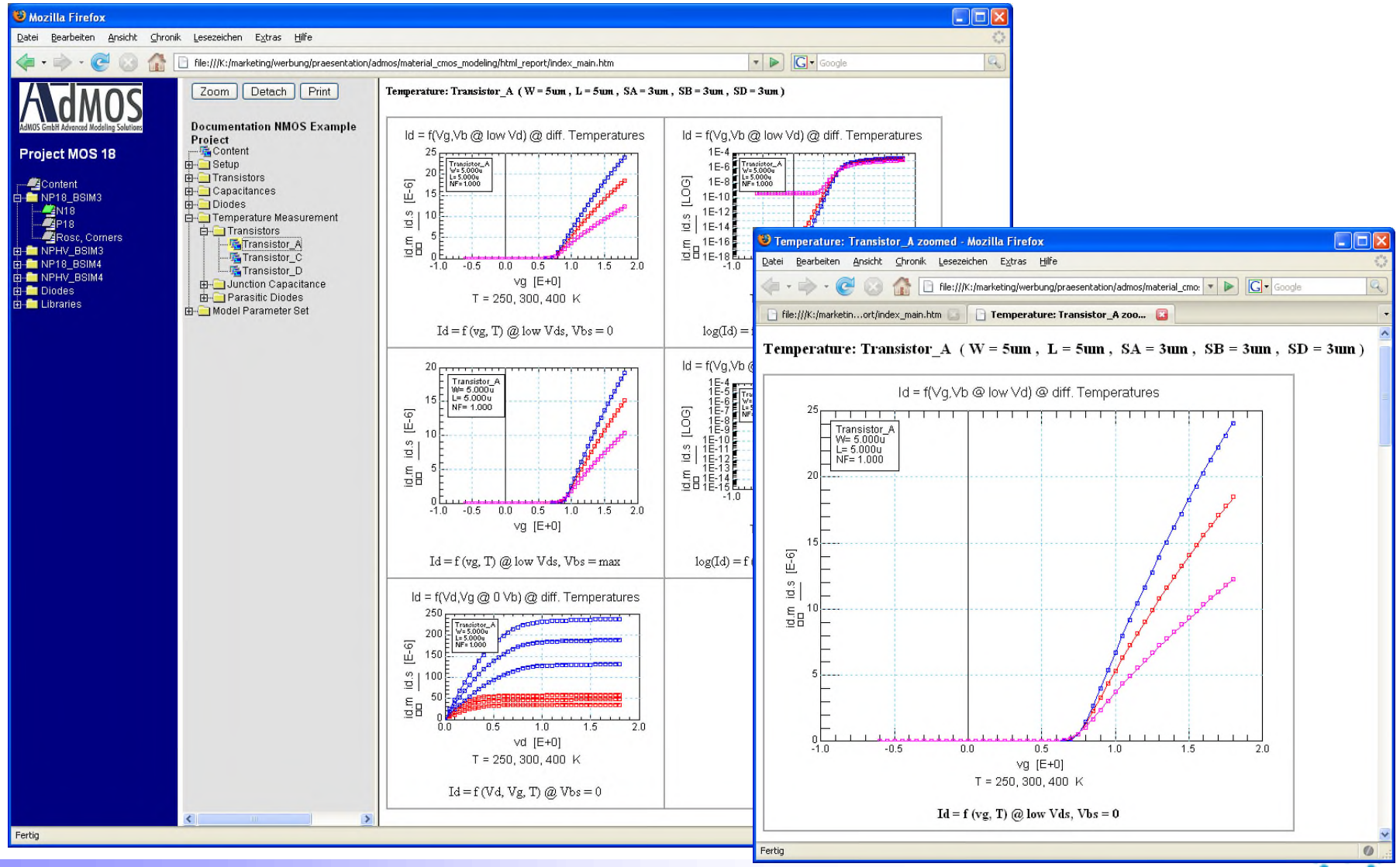
- Corner Modeling adds statistical information to extracted model parameter sets of BSIM3, BSIM4 or PSP or any other model.
- It uses process parameters for different measurement points (e.g. vtlin or idsat) to generate the industry standard corner cases fast, typical and slow.
- The result of this modelling is tested against simulation warnings or errors and can be documented in an HTML report including different transistors sizes as well as scaling plots for each PCM measurements and all corner cases.



AdMOS

Agilent Technologies

Documentation



AdMOS

Agilent Technologies

Summary

- A complete flow to generate high quality Next Generation Models (PSP, EKV3, HiSIM2) is demonstrated.
- Due to the very general nature of these procedures, it is possible to apply those extractions to any kind of new model.
- Next steps will include the support of new standard HV MOS models like HiSIM HV.